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ARKANSAS-RED RIVER BASINS WATER QUALITY CONSERVATION. APPENDIX VOLUME II. BENEFITS EVALUATION

Public Health Service
Washington, D. C.

June 1964

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Arkansas-Red River Basins

WATER QUALITY CONSERVATION

APPENDIX
VOLUME II · BENEFITS EVALUATION

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Arkansas-Red River Basins

WATER QUALITY CONSERVATION

APPENDIX
VOLUME II - BENEFITS EVALUATION

The Value of Benefits Attributable to an Improvement of Water Quality in the Basins of the Arkansas and Red Rivers and the General Areas Likely to be Benefited

Details of illustrations in
this document may be better
studied on microfiche.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Division of Water Supply and Pollution Control
Washington, D.C. 20201
June 1964

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I. INTRODUCTION

This volume, Benefits Evaluation, presents detailed information concerning: The value of benefits attributable to an improvement of water quality in the Arkansas-Red River basins, and the general areas likely to be benefited, based upon anticipated water supply needs of the area resulting from the expected economic growth. Special emphasis is given those segments of the economy which are likely to have the greatest influence on future water use of the Arkansas-Red River basins and adjoining areas. A detailed description of this area, as outlined in Figure I-1, is presented in Volume I of this appendix.

General

Four factors are involved in the future economic growth prospects of the Arkansas-Red River study area. These factors are (1) the condition of the national economy; (2) the oil and gas and other natural resource situation; (3) the geographic location of the basin; and (4) the development of the water resources of the two large river systems.

The condition of the national economy is best indicated by its growth rate as measured by population, employment, and gross national product. According to the Economic Task Group of the AD HOC Water Resources Council Staff, 1/ the population of the Nation will reach 502 million by 2020, an increase of 178 percent; employment will reach 197 million, an increase of 186 percent; and the gross national product will reach $4.5 trillion, an increase of 778 percent. These expectations indicate a thriving national economy in which the Arkansas-Red River basins will participate. That is, the future prospects of the basins are closely related to national conditions.

Petroleum and natural gas account for 69 percent of the Nation's energy requirements and 67 percent of the Nation's value of mineral fuel. Their potential for the growing petrochemical industry is increasing. In the light of these factors, the significance of oil and gas in the national economy can hardly be overstated.

The Arkansas-Red River basins study area produced approximately one-fourth of the Nation's oil and gas in 1960. At the same time, much of the petroleum and natural gas produced in the study area was marketed and refined in other regions. 2 3/

Oil and gas production in the future is expected to increase enough to hold its place in the national demand pattern for fuel increases to provide feedstock for the petrochemical industry.

Future years should show more in-basin processing of locally produced gas and oil. This increase would be attributable to expected low cost navigation transportation and increasing market size in the Midwest. These factors will make the area more competitive and stimulate regional growth in these products.

The forest industry in the eastern portion of the study area is expected to continue trends of devoting more land to softwoods with less land being utilized for hardwood. Pulpwood produced by these forests will continue to be valuable to the study area's growing pulp and paper industry.

Agriculture in the study area will continue to increase its output in response to regional and national demands for its products. This increase in production will be associated with additional gains in agricultural productivity. By 2020, the study area should be able to triple its output using half the number of workers employed in 1960. Associated with this increased agricultural production will be the need for equipment and fertilizer. Much of this increased agricultural output will be accomplished through increased irrigation. (A complete discussion of irrigation potential and projections is presented later in this Chapter.) Many of the agricultural products produced in the study area will be processed locally, as shown by projections of the food and kindred industries in this Chapter.

The geographic location of the basin constituted a considerable handicap early in the century since the major concentrations of population and economic activity were far distant. This locational handicap has been greatly reduced by improved transportation manifested by the highway and air transportation routes as well as by the railroad network of the study area. Continued improvement can be expected in the highways and air facilities. The major improvement in the locational situation, however, arises from the southward and westward trend of the national center of population. The center is now at Salem, Marion County, Illinois, about 50 miles east of St. Louis, Missouri, a shift of 45 miles westward since 1950. This shift and its expected continuance is contributing to the growth of population and markets in the basin, particularly of the large urban and metropolitan areas. The shift is also influencing the size of large population centers in proximity to the region, especially in proportion to the rest of the Nation. Much of this new and expected growth is within one-days trucking or rail distance from basin centers. Therefore, industrial operations seeking a production and distribution base relatively nearby these new markets of the northern and southern Midwest will look more favorably than in the past on the Arkansas-Red River basins for sites.

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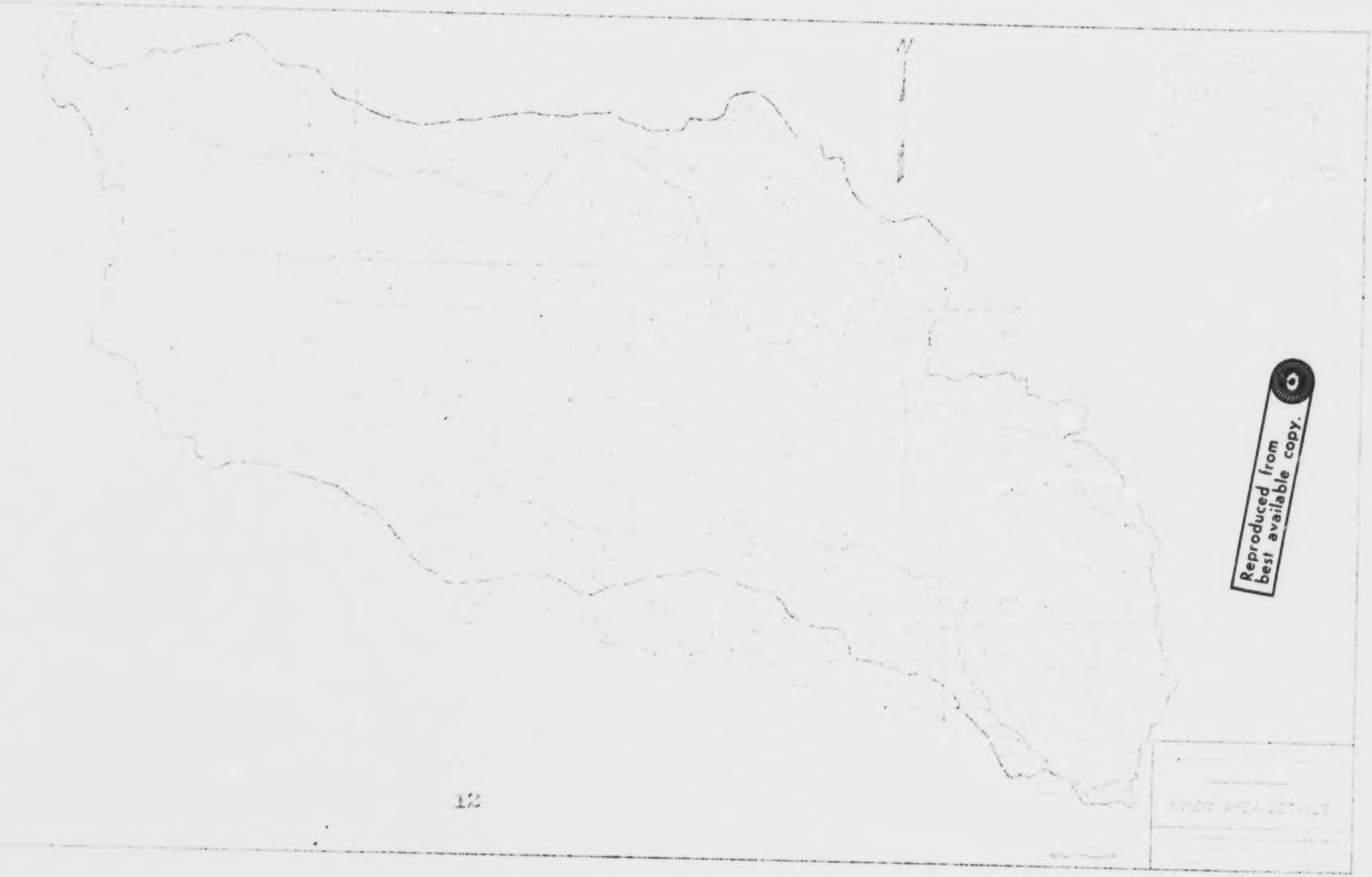

N
STUDY AREA DETAILS

FIGURE 1-1

With the transfer of NASA operations to Houston, Texas, the western tip of the Gulf Coast "Space Age Crescent" (Kennedy to Houston) has become the center of activity for this newest of man's great enterprises. Proximity of the Arkansas-Red River basins study area to this budding industry has already been felt in buildup of many new industries to supply space exploration needs. As the space industry grows to maturity, other needs will develop and with the many advantages the Arkansas-Red River basins area has to offer, it should logically become a center of production to meet some of these needs.

The area's climatic advantages form an attraction for "footloose industries" which can locate without considering resources or market availability. Such industry usually finds the needed labor force has already recognized the climatic advantage. This is true in the study area, since the labor force is available to accommodate industrial expansion. The mobility of labor within the study area allows movement of people to areas where industry develops.

The fourth factor influencing the growth of the basin involves the two river systems themselves. That is, the two major rivers and their tributaries represent an asset in a current condition of less than optimum development. The rivers can be altered in their performance and use to facilitate or enhance economic activities and to provide essential services and benefits. That is, the river systems can be managed to serve specifically determined purposes in accord with a systematic appraisal of their usefulness. A considerable effort in this regard has already been made as manifested by various flood control structures and reservoirs throughout the area. Also, an active pollution control program is underway among the States with Federal participation and assistance. Plans for navigation and further flood control and multiple-purpose structures also indicate acceptance of the objective of major development and management of this river-systems asset. As has been experienced in other parts of the country, extensive developments of inland waterways will offer not only economical transportation, but will open new markets, both in the United States and abroad, which were previously inaccessible because of transportation costs. At the present time, navigation projects have been authorized for the Arkansas River to Tulsa, Oklahoma, and the Red and Ouachita Rivers in Arkansas to Louisiana. Projects are proposed for navigation on the Red River to Denison, Texas; the Trinity River to Fort Worth; and the Central Oklahoma project to Oklahoma City, Oklahoma.

As significant as these efforts are for the future growth of the region, the development and management of the water quality aspects of these river systems on a comprehensive basis is necessary to assure enhancement of their potential.

Labor force projections shown in Table I-1 indicate the expected changes in employment patterns for the study area by the year 2020. Study area manufacturing employment should more than triple with this segment of employment increasing to 20 percent of the total labor force. The category "All Other Employed", which includes government and services of various types, is also expected to triple with this group accounting for 72 percent of the labor force in 2020.

Table I-1

Labor Force Projections
for the Study Area 2020

	1960		2020	
Major Industry Group	Number*	Percent	Number*	Percent
Agriculture**	311	9	150	1
Mining	90	3	250	3
Manufacturing	567	17	1,900	20
All Other Employed	2,256	67	6,750	72
Unemployed	144	4	370	4
Total Labor Force	3,368	100	9,420	100

* Thousands of people.
** Includes a small number (less than 1 percent) employed by Forestry and Fisheries.

Source: Bureau of the Census 4/

Population

2020 Projections

Considering the relative past and future economic position of the study area, as previously outlined, and the historic population trends, a projection is made for the study area population to the year 2020. These many factors are weighed, in relation to the Nation's past performance and future prospects, to establish the region's potential for population growth.

For planning purposes in this study, national economic growth projections of the Economic Task Group of the AD HOC Water Resources Council staff were adopted as representative of the future growth of the Nation. 1/ This established a national 2020 population of 502 million. This projection falls between the Bureau of the Census No. II and No. III projections for the Senate Select Committee on National Water Resources. 5/

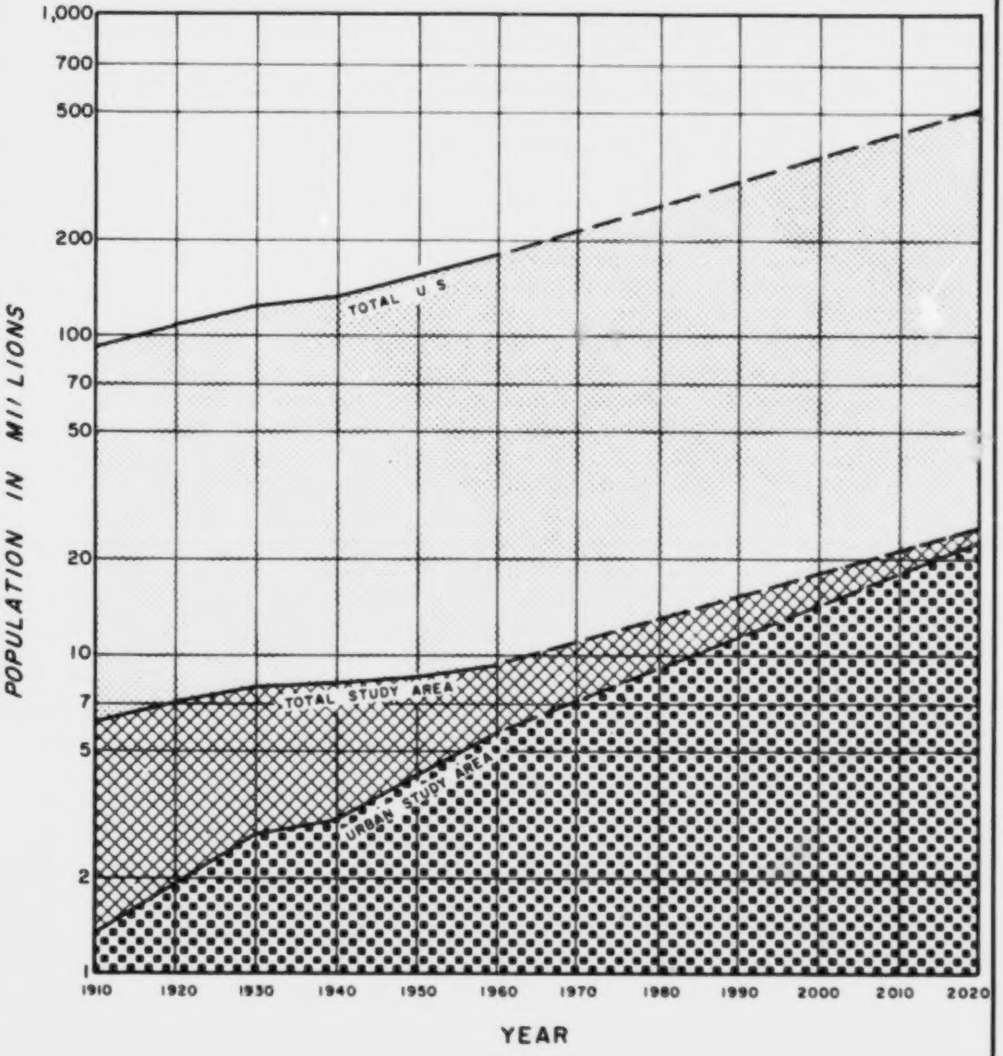
An analysis of the overall study area potential in relation to its competitive position in the Nation resulted in a 2020 population allocation of 24.47 million of the national projection to the Arkansas-Red River basins area. Historic trends and projections are depicted in Figure I-2. Having established a total study area population for 2020, cognizance is taken of the effects of the region's transition from an agrarian to an industrial, urbanized economy. As shown in Figure I-2, the trend toward urbanization is strong. Based on the assumed future relationship of urban to rural dwellers, a 2020 urban population of 22.4 million is expected.

The next step of the analysis was to allocate the total projected population to each of the 82 subareas to facilitate determination of future municipal water requirements.

The subareas, as described in Volume I and shown on Figure I-3, are classified according to their population characteristics and designated as Standard Metropolitan Statistical Area (SMSA), population centers, or rural subareas. An SMSA subarea is a group of counties containing at least one SMSA. The Texarkana SMSA is included in two subareas (T-17 and A-9) to respect political boundaries, since the SMSA is partly in Texas and partly in Arkansas. A population center subarea contains at least one county with a population of 30,000 or more and adjacent influenced counties. The remaining counties were grouped to provide a minimum 1960 total population of 20,000 or more and are referred to as rural.

The subareas containing SMSA's were examined first, since SMSA's presently account for almost one-half of the study area population and well over one-half of the national population. 6/ From examination of the economic base and historical population trends of study area SMSA subareas, in relation to the entire study area, projections were developed for each. Historically, study area SMSA population has increased at a more rapid rate than the national SMSA population. The projected 2020 population of the 14 subareas containing SMSA's totals 17.5 million or about 71 percent of the projected study area population. Individual projection for these subareas are presented in Figures I-4 through I-16.

Those subareas classified as Population Centers are the potential SMSA's of the future; therefore, their competitive position in the study area was analyzed next and population projections prepared for these 28 subareas. The remaining projected study area population is allocated to the 40 rural subareas following examination of their relative potential to support growth. Historic and projected distribution of population by subarea type is shown in Table I-2. Historic trends and 2020 projections for all subareas are presented in Table I-3.

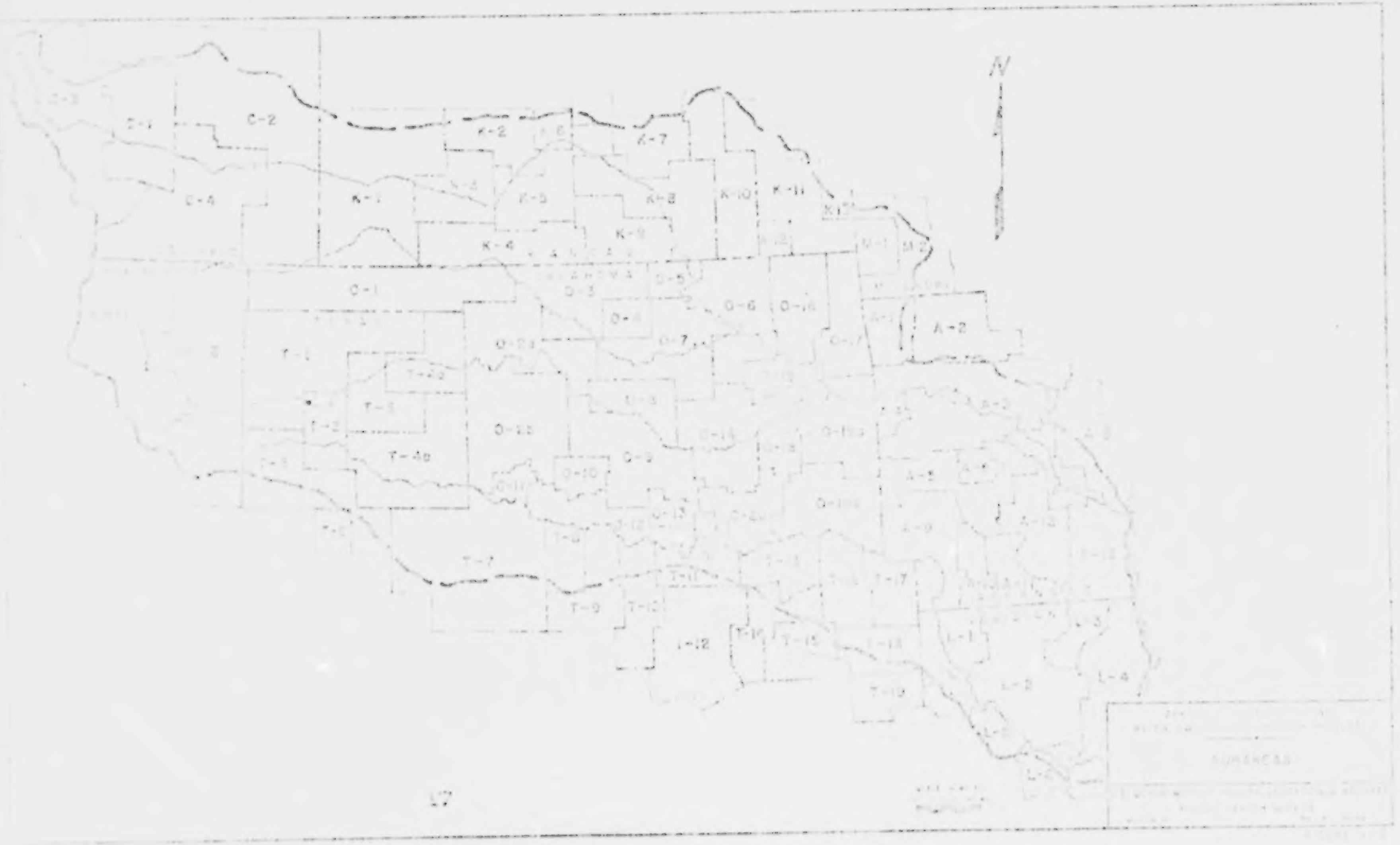


ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

POPULATION TRENDS & PROJECTIONS
NATIONAL AND STUDY AREA

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE I-2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OKLAHOMA
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O-19b
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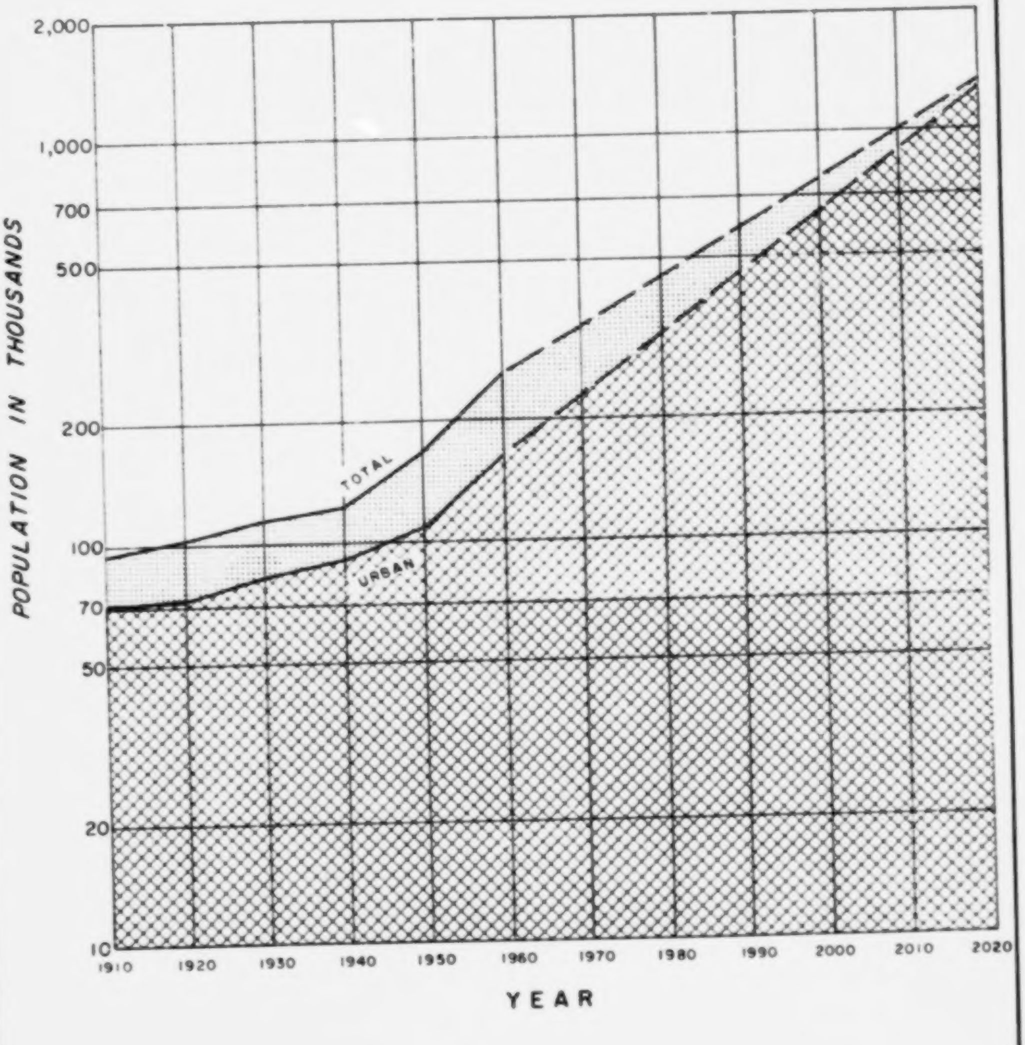
SUBAREAS



ARKANSAS-RED RIVER BASINS
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POPULATION TRENDS & PROJECTIONS

PUEBLO-COLORADO SPRINGS SUBAREA C-1

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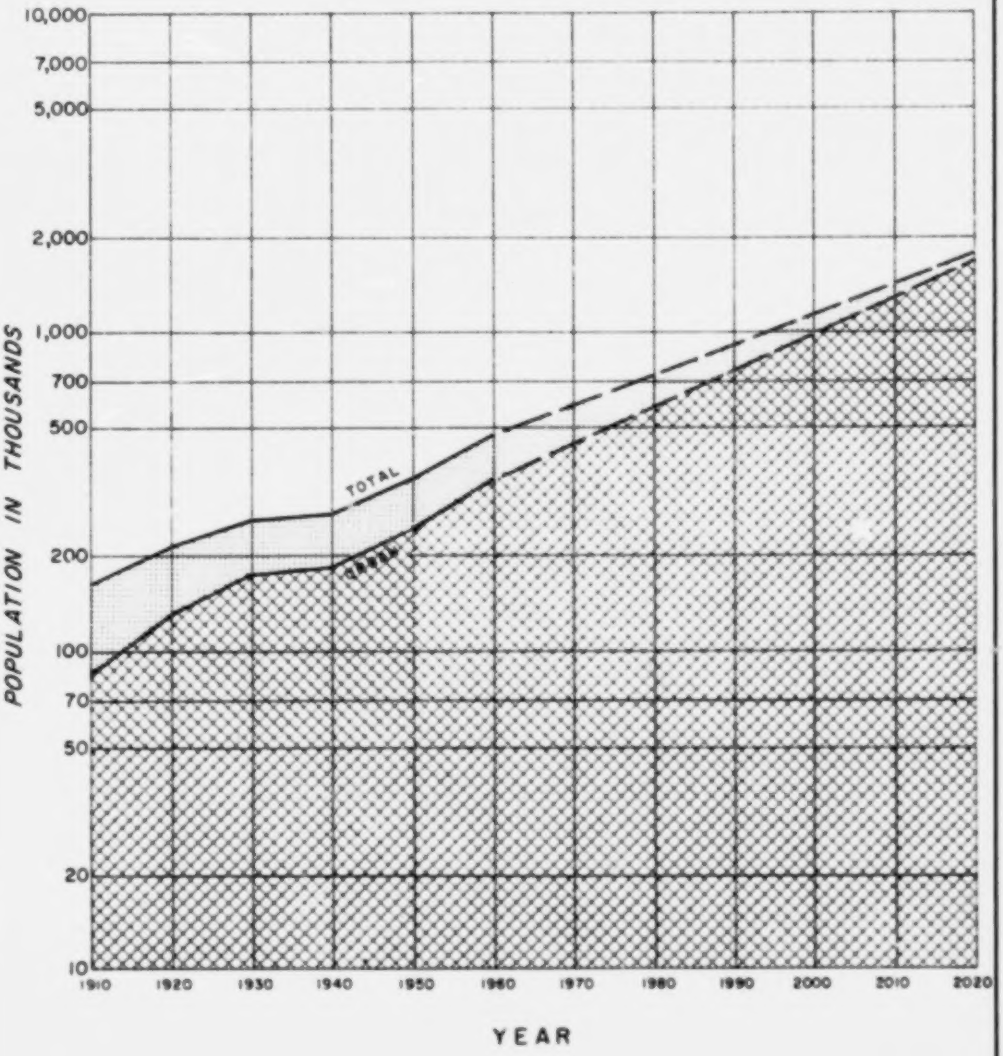
FIGURE 1-4



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POPULATION TRENDS & PROJECTIONS

WICHITA SUBAREA K–8

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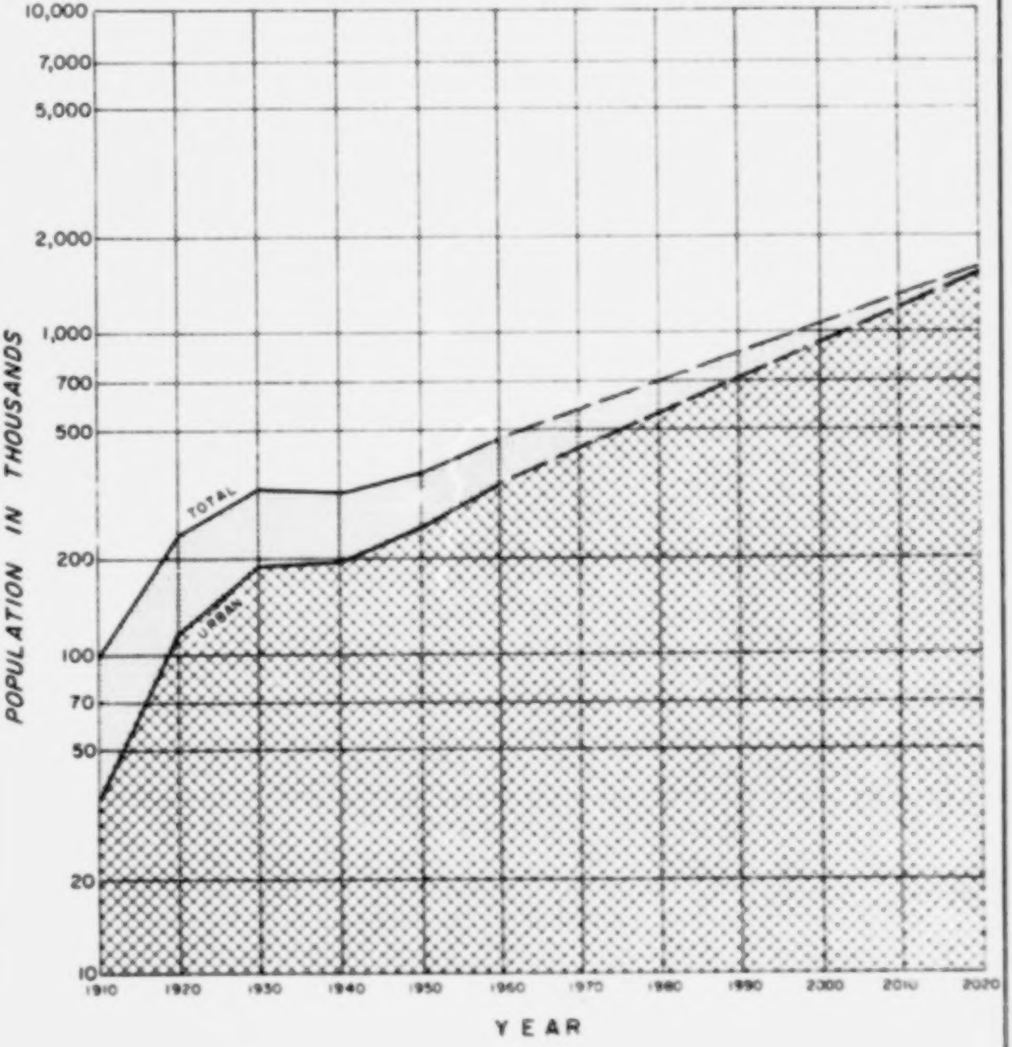
FIGURE I – 5



ARKANSAS–RED RIVER BASINS
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POPULATION TRENDS & PROJECTIONS
TULSA SUBAREA O–6

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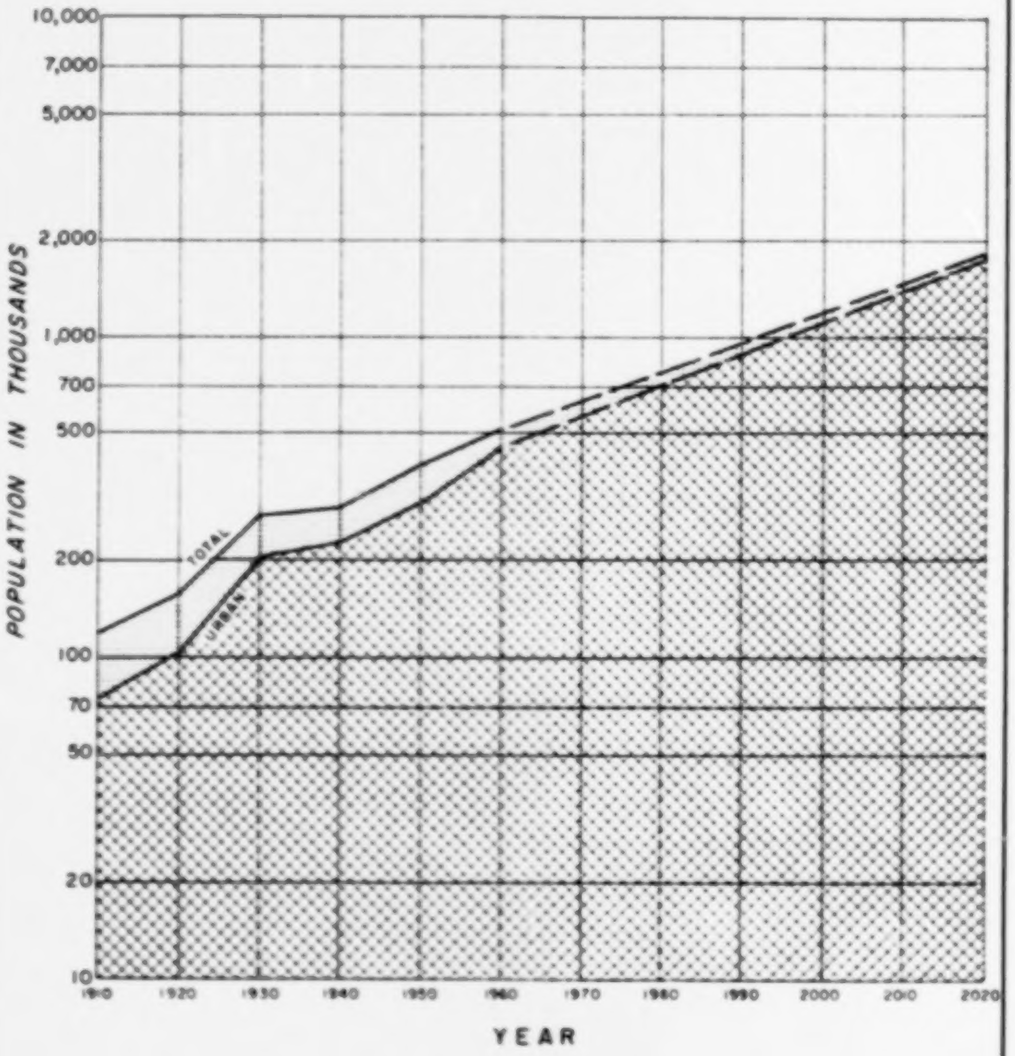
FIGURE I–6



ARKANSAS–RED RIVER BASINS
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POPULATION TRENDS & PROJECTIONS

OKLAHOMA CITY SUBAREA O–8

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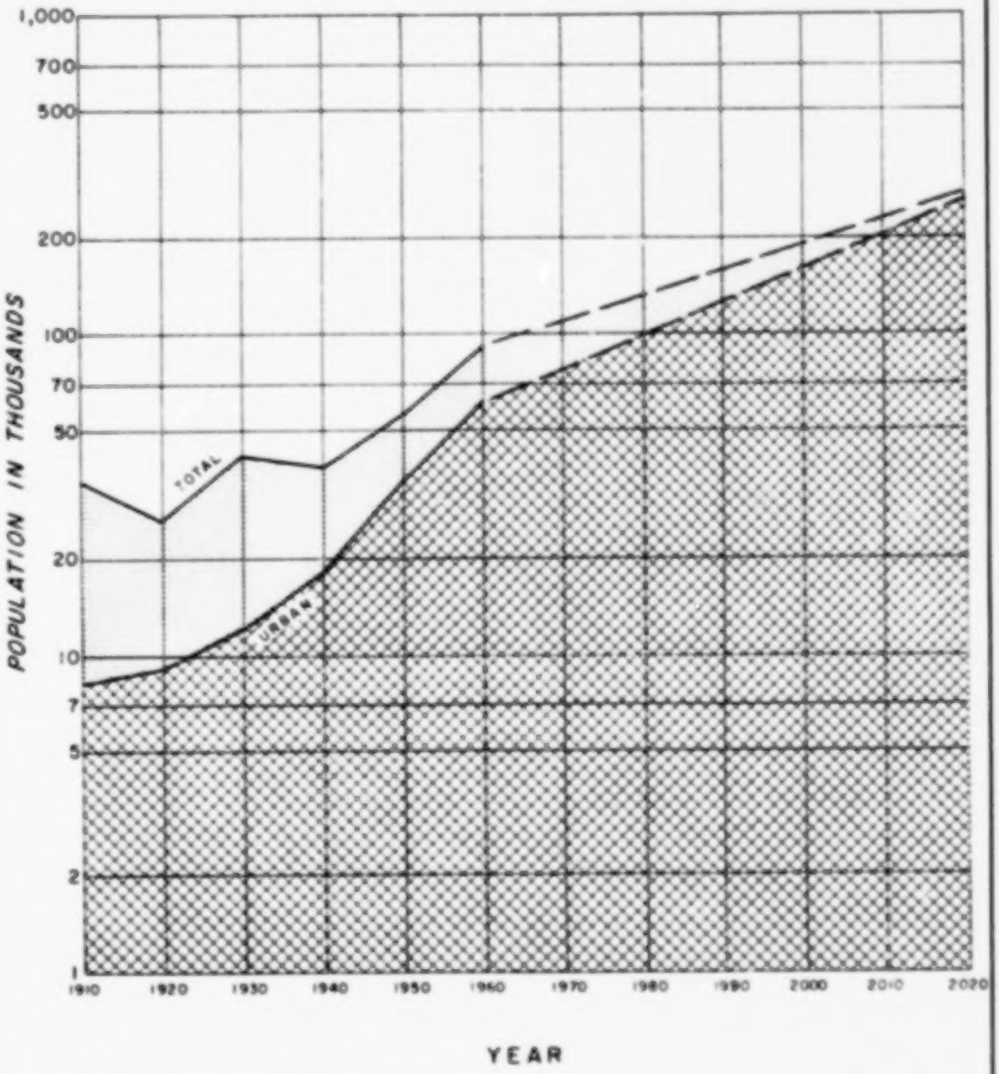
FIGURE I–7



ARKANSAS-RED RIVER BASINS
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POPULATION TRENDS & PROJECTIONS

LAWTON SUBAREA 0-10

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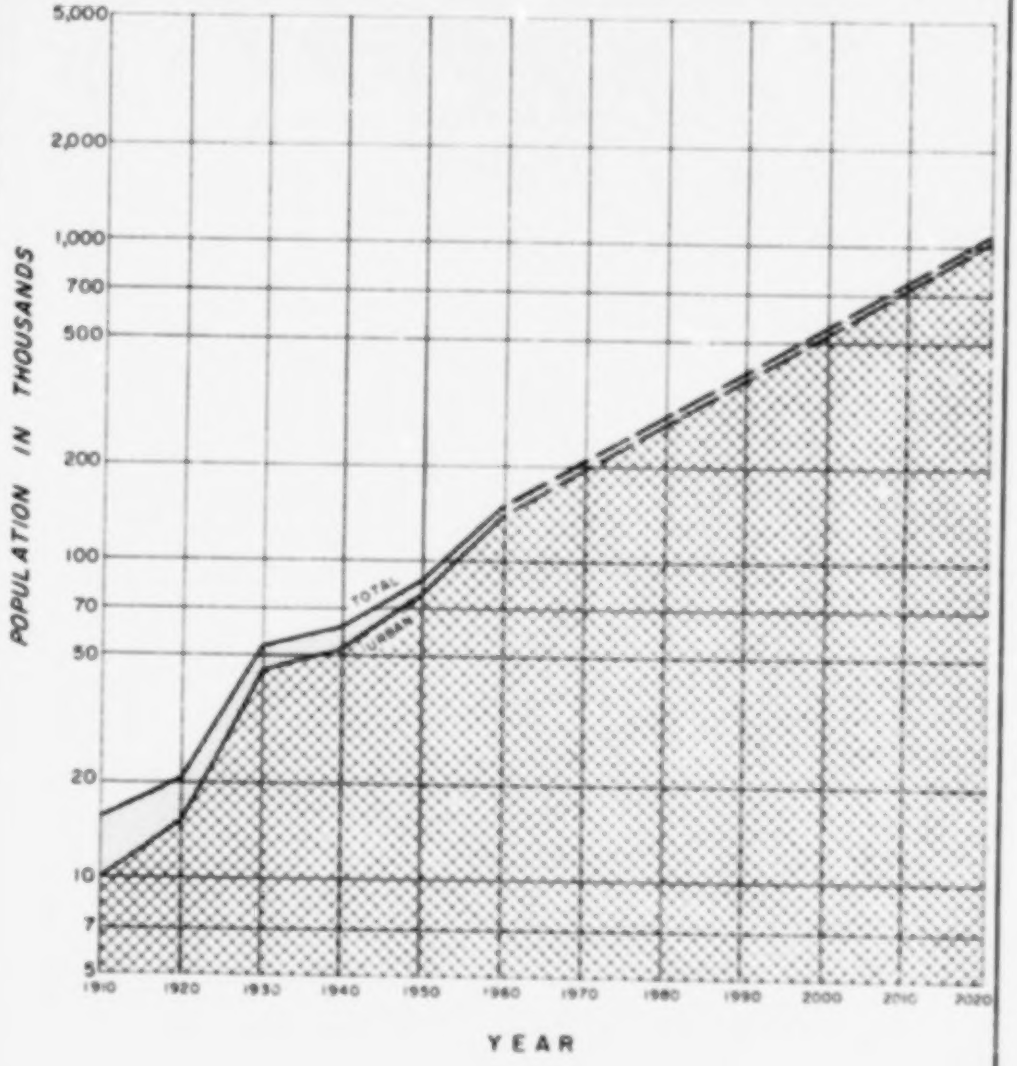
REGION VII DALLAS, TEXAS

FIGURE 1-8



ARKANSAS – RED RIVER BASINS
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POPULATION TRENDS & PROJECTIONS

AMARILLO SUBAREA T – 2

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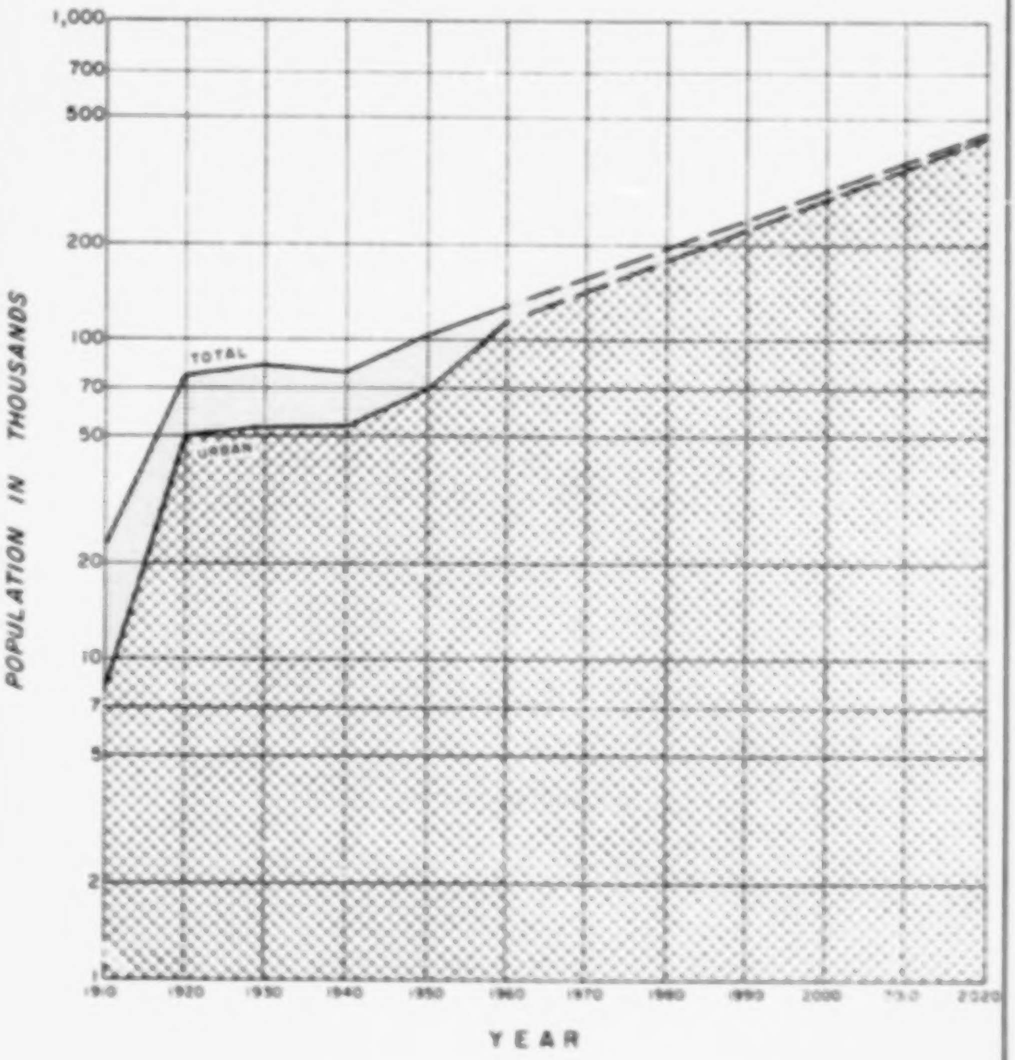
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 1 – 9



ARKANSAS - RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

POPULATION TRENDS & PROJECTIONS
WICHITA FALLS SUBAREA T-8

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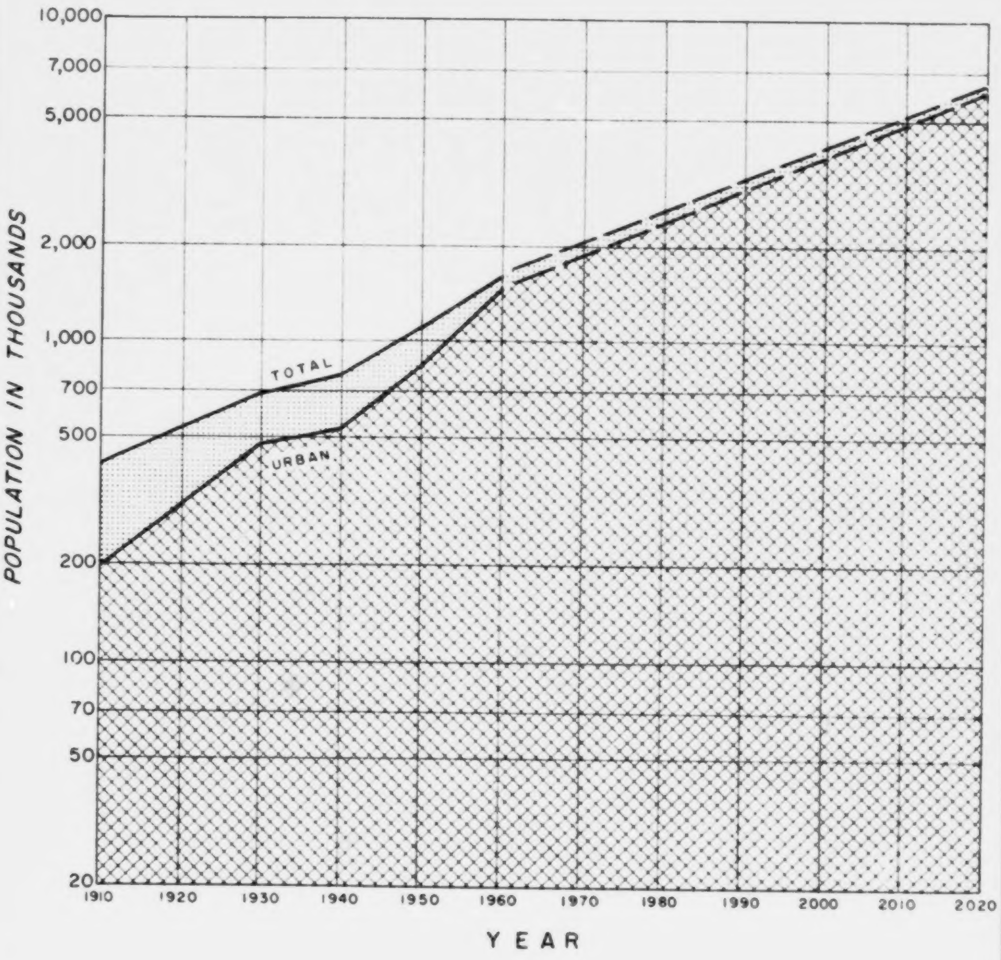
REGION VI DALLAS, TEXAS

FIGURE 1-10



ARKANSAS – RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

POPULATION TRENDS & PROJECTIONS

DALLAS–FORT WORTH SUBAREA T-12

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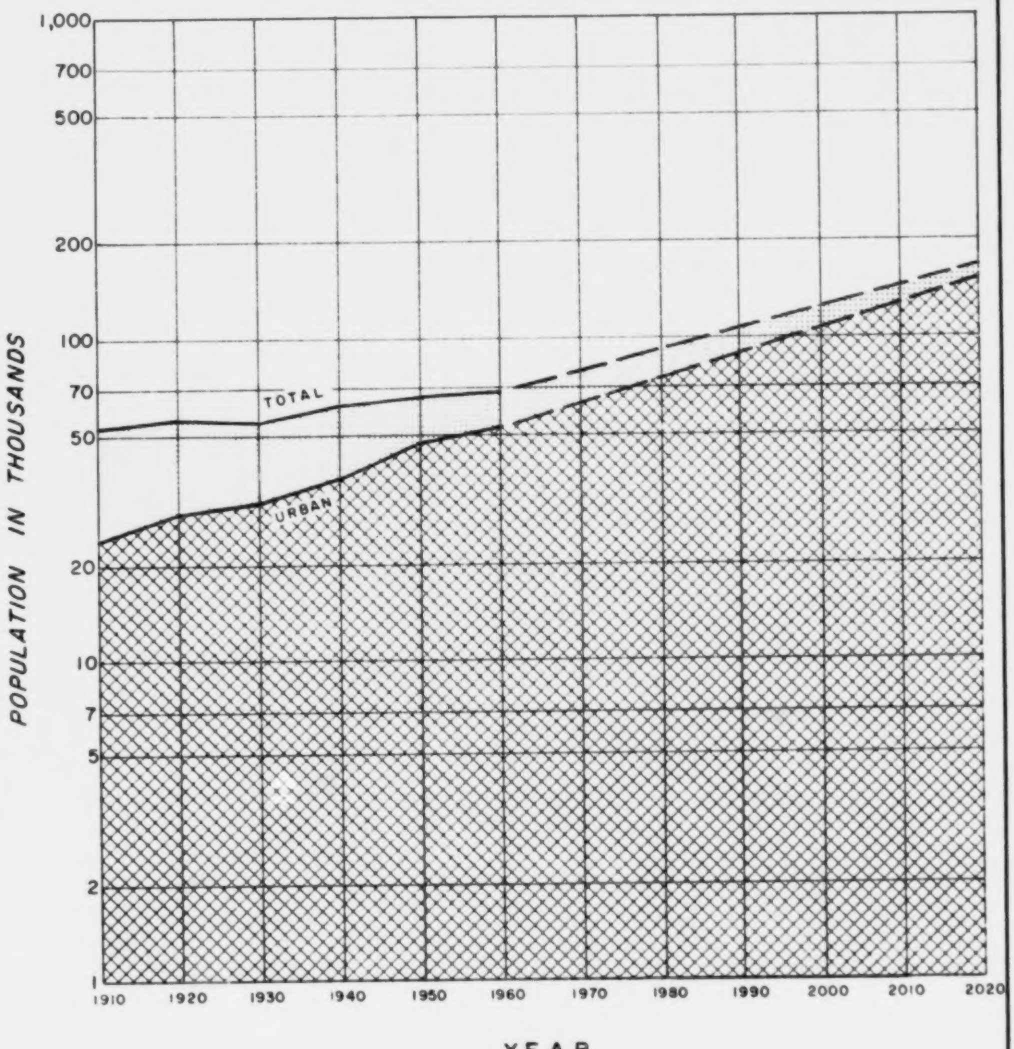
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE I – 11



ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

POPULATION TRENDS & PROJECTIONS
FORT SMITH SUBAREA A-4

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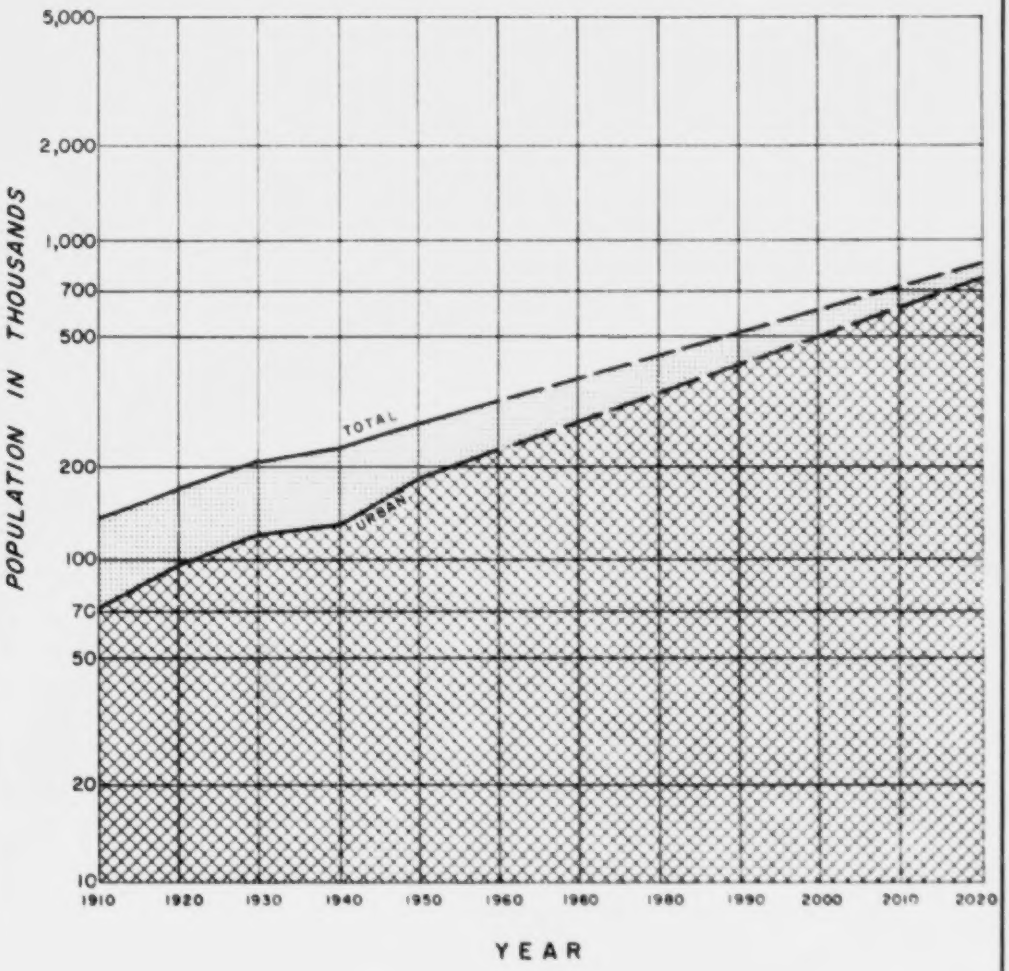
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 1-12



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POPULATION TRENDS & PROJECTIONS

LITTLE ROCK SUBAREA A-7

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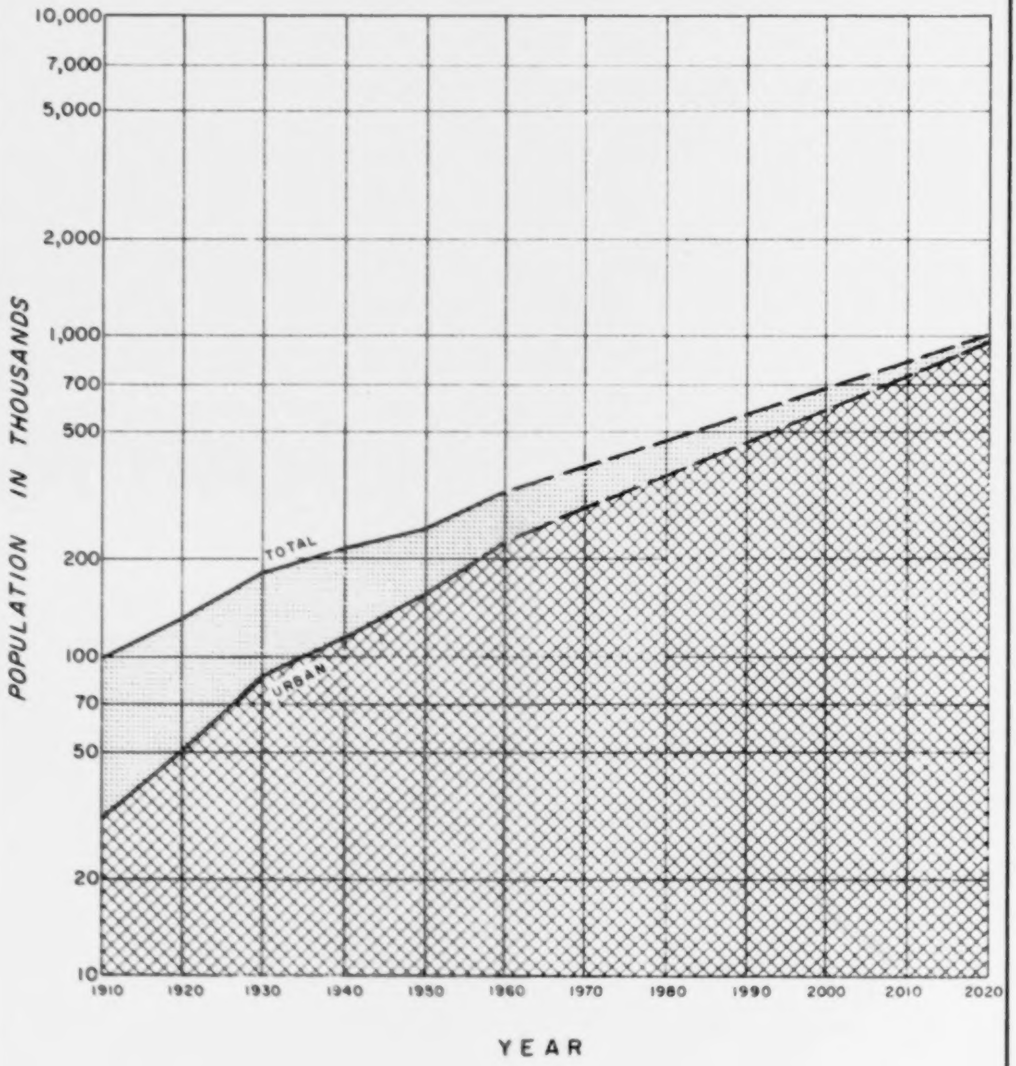
FIGURE 1-13



ARKANSAS – RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

POPULATION TRENDS & PROJECTIONS

SHREVEPORT SUBAREA L-1

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PUBLIC HEALTH SERVICE
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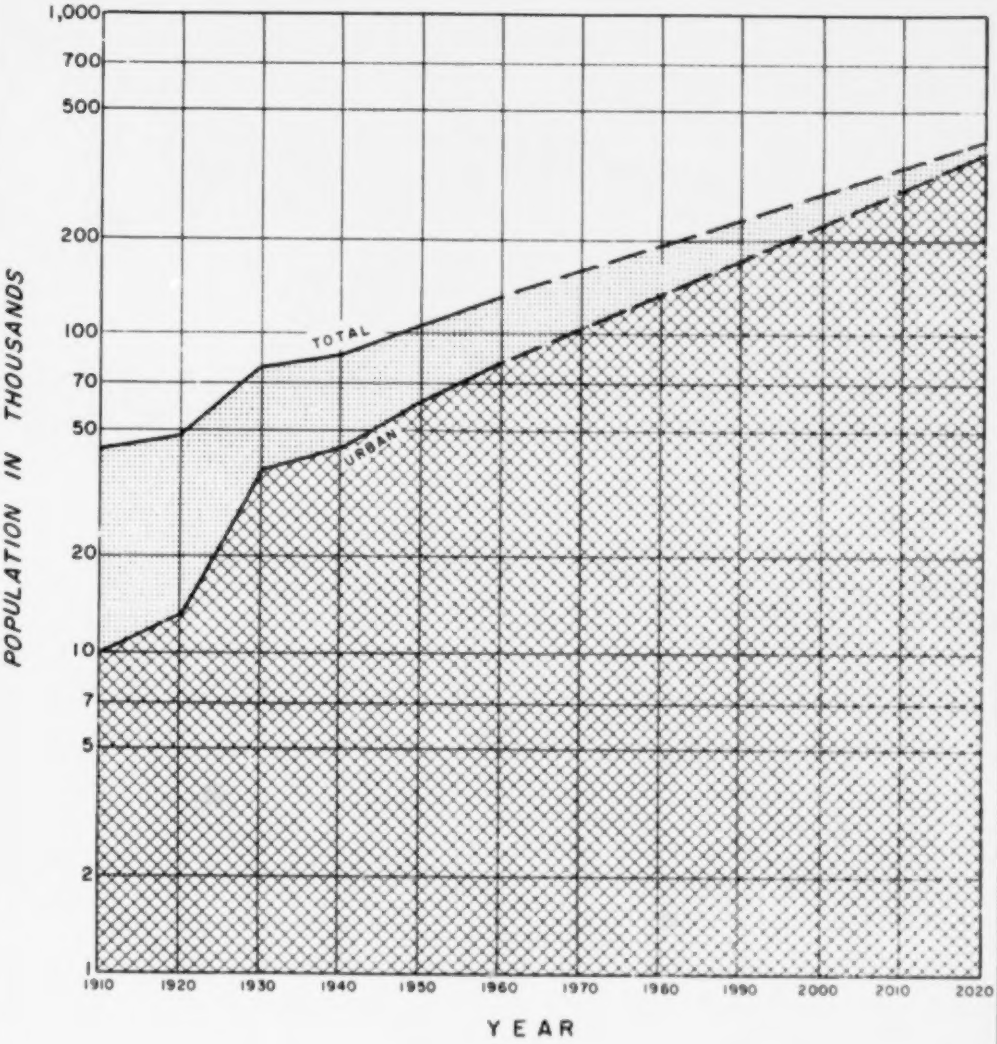
FIGURE 1-14



ARKANSAS-RED RIVER BASINS
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POPULATION TRENDS & PROJECTIONS

MONROE SUBAREA L-3

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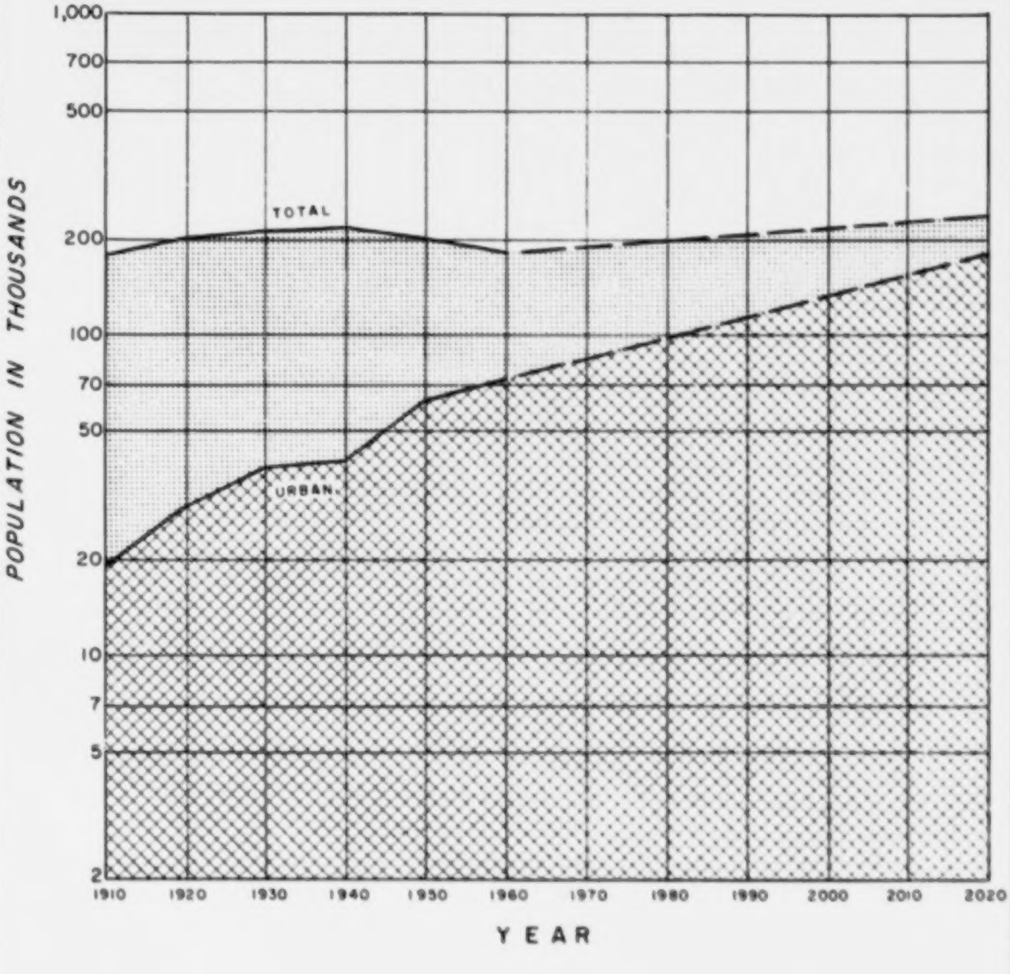
FIGURE I-15



ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

POPULATION TRENDS & PROJECTIONS

TEXARKANA SUBAREA A-9 & T-17

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 1-16

Table I-2

Study Area Population Distribution by Subarea Type
1910, 1960, and Projected 2020

Subarea Type	Number of Sub-areas	1910 Population (mil.)	1910 % of Total	1960 Population (mil.)	1960 % of Total	2020 Population (mil.)	2020 % of Total
SMSA	14	1.5	25	4.8	52	17.5	71
Population Center	28	1.9	31	2.2	23	3.7	15
Rural	40	2.7	44	2.3	25	3.3	14
Total	82	6.1	100	9.3	100	24.5	100

Source: Bureau of the Census 6/

2070 Projections

The projects being considered for control of natural brine pollution are expected to have a useful life of at least 100 years. Therefore, it is necessary to determine water requirements and benefits to water quality improvement for a 100-year period, 1970-2070. As previously described, 2020 water needs were determined by detailed economic studies of population, resources, and industrial output. A projection of population is relied on as an indicator of 2070 water use. This approach is based on the assumption that the ratio of total population to total water requirements will remain the same in 2070 as in 2020.

After 2020 the study area growth is expected to continue with the 2070 population reaching 42 million.

Future Growth of Large Water-Using Industries

General

Appraisal of the future growth potential of large water-using industries in the study area is a necessary step in assessing the need for water resource development. Analysis of study area growth potential in these industries, however, requires consideration of the national economy because of the influence of national factors on future developments. In projecting future growth of large water-using industries in the study area, the attempt is therefore made, where possible, to establish a growth relationship between these phases of study area and national economy. With this relationship established, an estimate of the potential volume and nature of industrial activities which might originate in the study area was made.

Table I-3

Study Area Populations by Subareas
1930, 1960, and 2020

Map Designation	Area	Type	Component	Population - Historic and Projected 1930	1960	2020
Colorado						
C-1	Pueblo-Colorado Springs	SMSA	Total	95,544	262,449	1,350,000
			Urban	70,825	165,001	1,265,000
			Rural	24,719	97,448	85,000
C-2	Lamar	Rural	Total	37,353	40,795	45,000
			Urban	2,977	7,369	32,000
			Rural	34,376	33,426	13,000
C-3	Canon City	Rural	Total	68,513	49,084	53,000
			Urban	19,807	25,433	40,000
			Rural	48,706	23,651	13,000
C-4	Trinidad	Rural	Total	80,400	55,508	51,000
			Urban	19,116	27,068	35,000
			Rural	61,284	28,440	16,000
New Mexico						
NM-1	Raton	Rural	Total	52,061	43,302	50,000
			Urban	11,529	21,964	38,000
			Rural	40,532	21,338	12,000
NM-2	Clovis	Pop. Center	Total	37,759	52,912	80,000
			Urban	5,781	35,170	67,000
			Rural	31,978	17,742	13,000
Kansas						
K-1	Garden City	Rural	Total	33,456	69,536	184,000
			Urban	3,171	35,248	167,000
			Rural	30,285	34,288	17,000
K-2	Larned	Rural	Total	22,568	21,884	25,000
			Urban	2,911	5,001	18,000
			Rural	19,657	16,883	7,000
K-3	Dodge City	Rural	Total	17,444	28,433	56,000
			Urban	3,214	13,520	49,000
			Rural	14,230	14,913	7,000
K-4	Medicine Lodge	Rural	Total	22,365	20,885	24,000
			Urban	-----	3,072	19,000
			Rural	22,365	17,813	5,000
K-5	Pratt	Rural	Total	51,979	43,226	47,000
			Urban	3,902	12,748	38,000
			Rural	48,077	30,478	9,000
K-6	Great Bend	Pop. Center	Total	17,876	32,368	78,000
			Urban	4,622	23,647	72,000
			Rural	13,254	8,721	6,000
K-7	Newton	Rural	Total	73,580	72,970	102,000
			Urban	11,408	27,482	79,000
			Rural	62,172	45,488	23,000
K-8	Wichita	SMSA	Total	165,797	478,562	1,775,000
			Urban	86,151	348,902	1,645,000
			Rural	79,646	129,660	130,000
K-9	Wellington	Rural	Total	57,076	44,815	57,000
			Urban	12,273	15,135	44,000
			Rural	44,803	29,680	13,000
K-10	Eureka	Rural	Total	57,561	33,570	36,000
			Urban	2,565	6,719	26,000
			Rural	54,996	26,851	10,000
K-11	Emporia	Rural	Total	190,371	138,739	168,000
			Urban	37,440	70,785	135,000
			Rural	152,931	67,954	33,000
K-12	Coffeyville	Pop. Center	Total	69,476	45,007	55,000
			Urban	51,068	34,069	45,000
			Rural	18,408	10,938	10,000
K-13	Pittsburg	Pop. Center	Total	51,178	37,032	65,000
			Urban	18,151	18,678	55,000
			Rural	33,027	18,354	10,000
Oklahoma						
O-1	Guymon	Rural	Total	40,422	31,479	39,000
			Urban	-----	5,768	30,000
			Rural	40,422	25,711	9,000
O-2a	Woodward	Rural	Total	64,059	37,487	44,000
			Urban	2,696	10,999	33,000
			Rural	61,363	26,488	11,000
O-2b	Clinton	Rural	Total	134,128	91,587	102,000
			Urban	13,460	40,902	79,000
			Rural	120,668	50,685	23,000
O-3	Alva	Rural	Total	69,713	36,325	38,000
			Urban	3,688	6,258	27,000
			Rural	66,025	30,067	11,000
O-4	Enid	Pop. Center	Total	39,050	52,975	96,000
			Urban	13,799	38,859	85,000
			Rural	25,251	14,116	11,000
O-5	Ponca City	Pop. Center	Total	26,999	51,062	85,000
			Urban	5,787	37,636	76,000
			Rural	21,212	13,426	9,000
O-6	Tulsa	SMSA	Total	98,803	461,321	1,600,000
			Urban	35,422	338,940	1,530,000
			Rural	63,381	122,381	70,000
O-7	Stillwater	Pop Center	Total	161,376	113,571	150,000
			Urban	30,789	55,588	123,000
			Rural	130,587	57,983	27,000
O-8	Oklahoma City	SMSA	Total	327,576	531,833	1,820,000
			Urban	275,802	463,919	1,800,000
			Rural	51,774	67,914	20,000
O-9	Duncan	Pop. Center	Total	143,194	147,853	190,000
			Urban	22,872	67,290	151,000
			Rural	120,322	80,563	39,000
O-10	Lawton	SMSA	Total	36,117	90,803	287,000
			Urban	7,788	61,697	262,000
			Rural	28,329	29,106	25,000
O-11	Altus	Pop. Center	Total	23,737	29,738	69,000
			Urban	4,821	21,627	65,000
			Rural	18,916	8,111	4,000
O-12	Frederick	Rural	Total	49,119	36,739	42,000
			Urban	5,955	8,706	31,000
			Rural	43,164	28,033	11,000
O-13	Ardmore	Pop. Center	Total	25,318	39,044	68,000
			Urban	8,418	23,082	63,000
			Rural	16,900	15,962	5,000
O-14	Shawnee	Pop Center	Total	168,703	142,408	195,000
			Urban	20,078	69,883	155,000
			Rural	148,625	72,525	40,000
O-15	Muskogee	Pop Center	Total	73,838	98,811	160,000
			Urban	29,431	60,521	130,000
			Rural	44,407	38,290	30,000
O-16	Claremore	Rural	Total	85,045	83,511	120,000
			Urban	16,638	27,774	90,000
			Rural	68,407	55,737	30,000
O-17	Miami	Rural	Total	54,685	72,371	86,000
			Urban	5,798	5,840	56,000
			Rural	48,887	66,531	30,000
O-18	McAlester	Pop Center	Total	67,650	56,380	54,000
			Urban	17,621	17,419	47,000
			Rural	50,029	38,961	7,000
O-19a	Poteau	Rural	Total	86,328	63,966	70,000
			Urban	-----	7,779	43,000
			Rural	86,328	56,187	27,000
O-19b	Hugo	Rural	Total	52,661	50,570	73,000
			Urban	4,582	11,256	49,000
			Rural	48,079	39,314	24,000
O-20	Durant	Rural	Total	72,015	50,386	80,000
			Urban	5,330	16,470	56,000
			Rural	66,685	33,916	24,000

Table I-3

Study Area Populations by Subareas
1930, 1960, and 2020

Map Designation	Area	Type	Component	1930	1960	2020
Texas						
T-1	Dalhart	Rural	Total	10,585	43,367	150,000
			Urban	2,543	24,429	140,000
			Rural	8,042	18,938	10,000
T-2	Amarillo	SMSA	Total	15,736	149,493	1,050,000
			Urban	9,957	143,833	1,045,000
			Rural	5,779	5,660	5,000
T-3	Pampa-Borger	Pop. Center	Total	6,626	73,735	201,000
			Urban	-----	24,664	192,000
			Rural	6,626	49,071	9,000
T-4a	Canadian	Rural	Total	6,756	7,000	9,000
			Urban	-----	-----	7,000
			Rural	6,756	7,000	2,000
T-4b	Childress	Rural	Total	39,076	39,958	38,000
			Urban	3,818	15,981	27,000
			Rural	35,256	23,977	11,000
T-5	Hereford	Rural	Total	15,997	54,669	165,000
			Urban	-----	18,766	125,000
			Rural	15,997	35,903	40,000
T-6	Plainview	Pop. Center	Total	7,566	36,798	106,000
			Urban	2,829	18,735	90,000
			Rural	4,737	18,063	16,000
T-7	Vernon	Rural	Total	84,221	72,536	73,000
			Urban	6,322	24,510	53,000
			Rural	77,899	48,026	20,000
T-8	Wichita Falls	SMSA	Total	22,619	129,638	440,000
			Urban	8,700	117,399	436,000
			Rural	14,619	12,239	4,000
T-9	Graham	Rural	Total	42,517	33,023	60,000
			Urban	-----	19,255	50,000
			Rural	42,517	13,768	10,000
T-10	Weatherford	Rural	Total	77,906	56,705	84,000
			Urban	7,968	24,233	64,000
			Rural	69,950	30,152	20,000
T-11	Sherman	Pop. Center	Total	82,599	95,603	218,000
			Urban	33,668	60,819	200,000
			Rural	50,931	34,784	18,000
T-12	Dallas-Fort Worth	SMSA	Total	612,600	1,656,816	6,425,000
			Urban	397,100	1,500,353	6,365,000
			Rural	215,500	156,463	60,000
T-13	Paris	Pop. Center	Total	105,011	63,976	150,000
			Urban	16,113	28,316	133,000
			Rural	89,798	35,660	17,000
T-14	Greenville	Pop. Center	Total	122,540	93,797	160,000
			Urban	23,860	50,926	137,000
			Rural	98,680	42,871	23,000
T-15	Mineola	Rural	Total	55,855	39,737	45,000
			Urban	-----	3,810	28,000
			Rural	55,855	35,927	17,000
T-16	Mount Pleasant	Rural	Total	76,307	57,993	74,000
			Urban	5,137	18,807	52,000
			Rural	71,170	39,186	22,000
T-17	Texarkana	SMSA*	Total	62,416	83,667	132,000
			Urban	9,790	37,067	107,000
			Rural	52,626	46,600	25,000
T-18	Marshall	Pop. Center	Total	81,813	142,072	255,000
			Urban	19,122	84,216	220,000
			Rural	62,691	58,056	35,000
T-19	Henderson	Pop. Center	Total	67,370	53,291	75,000
			Urban	-----	14,928	53,000
			Rural	67,370	38,363	22,000
Missouri						
M-1	Joplin	Pop. Center	Total	116,809	108,956	130,000
			Urban	61,573	42,769	100,000
			Rural	55,236	66,187	30,000
M-2	Aurora	Rural	Total	107,910	80,841	97,000
			Urban	8,325	12,408	67,000
			Rural	99,585	68,433	30,000
Arkansas						
A-1	Fayetteville	Pop. Center	Total	67,218	92,066	136,000
			Urban	7,291	43,632	106,000
			Rural	59,927	48,437	30,000
A-2	Harrison	Rural	Total	72,660	50,557	56,000
			Urban	-----	6,580	30,000
			Rural	72,660	43,977	26,000
A-3	Van Buren	Rural	Total	237,031	161,180	232,000
			Urban	9,608	41,112	162,000
			Rural	227,423	120,068	70,000
A-4	Fort Smith	SMSA	Total	52,278	66,687	160,000
			Urban	23,975	52,991	152,000
			Rural	28,303	13,696	8,000
A-5	Benton	Rural	Total	85,030	89,110	122,000
			Urban	9,470	32,422	87,000
			Rural	75,560	56,688	35,000
A-6	Hot Springs	Pop. Center	Total	27,271	46,697	96,000
			Urban	14,434	28,337	81,000
			Rural	12,837	18,360	15,000
A-7	Little Rock	SMSA	Total	139,485	324,353	850,000
			Urban	72,181	225,326	770,000
			Rural	67,304	99,029	80,000
A-8	Stuttgart	Pop. Center	Total	176,420	108,443	133,000
			Urban	2,760	26,469	91,000
			Rural	173,660	82,044	42,000
A-9	Texarkana	SMSA*	Total	121,257	100,486	113,000
			Urban	9,294	37,216	80,000
			Rural	111,963	63,270	33,000
A-10	Magnolia	Rural	Total	43,164	37,300	52,000
			Urban	2,705	14,184	38,000
			Rural	40,459	22,916	14,000
A-11	El Dorado	Pop. Center	Total	52,497	81,150	160,000
			Urban	8,197	41,115	135,000
			Rural	44,300	40,044	25,000
A-12	Warren	Rural	Total	59,930	45,780	58,000
			Urban	2,796	10,642	39,000
			Rural	57,165	35,138	19,000
A-13	Crossett	Rural	Total	99,467	93,640	130,000
			Urban	-----	29,403	96,000
			Rural	99,467	64,237	34,000
Louisiana						
L-1	Shreveport	SMSA	Total	99,124	321,107	1,035,000
			Urban	31,017	226,542	975,000
			Rural	68,107	94,565	60,000
L-2	Ruston	Rural	Total	190,981	183,725	280,000
			Urban	4,302	46,819	200,000
			Rural	186,679	136,906	80,000
L-3	Monroe	SMSA	Total	44,616	135,372	422,000
			Urban	10,209	82,627	377,000
			Rural	34,407	52,745	45,000
L-4	Tallulah	Pop. Center	Total	132,175	176,250	215,000
			Urban	-----	44,528	135,000
			Rural	132,175	131,720	80,000
L-5	Natchitoches	Pop. Center	Total	36,455	35,653	57,000
			Urban	2,532	13,924	43,000
			Rural	33,923	21,729	14,000
L-6	Alexandria	Pop. Center	Total	44,565	111,351	315,000
			Urban	11,213	58,532	280,000
			Rural	33,352	52,819	35,000
			Grand Total	6,136,404	9,333,115	24,470,000
			Urban	1,323,493	5,663,243	22,378,000
			Rural	4,812,911	3,669,872	2,092,000

Source: Bureau of the Census 3/

Those industries which require large amounts of water in their manufacturing processes and for which future growth within the study area is projected include:

1. Thermal Power Generation
2. Petroleum Refining
3. Petrochemical Production
4. Natural Gas Processing
5. Pulp and Paper Manufacture
6. Primary Metals (iron, steel, and aluminum) Output
7. Food and Kindred Products Production

These industries are described in Senate Select Print No. 8 as "wet" or principal water-using industries. 7/ A discussion of future growth in all these industries, except food and kindred products, follows. In view of the extremely large number of water uses associated with the food and kindred industry and the complexity involved in projecting future production in many different categories of food processing, future growth and water needs in this industry are derived by other methods as discussed in Chapter III.

Thermal Power Generation

Because of geographical limitations, hydroelectric power is not expected to be of great significance as a source of future power supply in the study area. In general it is expected that these needs will largely be met by thermal power generation.

In projecting future study area thermal power requirements, cognizance was given to forecasts made by the Federal Power Commission, Edison Electric Institute, and U.S. Congressional Subcommittee. These projections were made with regard to the following:

1. Federal Power Commission - Senate Select Committee on National Water Resources - National Projections to 1980 8/

2. Edison Electric Institute - Senate Select Committee - National Projections to 1980 8/

3. U.S. Congressional Subcommittee - National Projections to 2000 7/

4. Federal Power Commission - National Projections to 2010 9/

As a basis for projecting future study area power needs, the above projections were extrapolated to 2020 and plotted as shown in Figure I-17. Beginning a national average per capita rate in 1960 of 12.5 kilowatt-hour per capita per day, projections ranged from 34 to 105 kilowatt-hours per capita per day by the year 2020.

Ebasco Services, Incorporated, conducted a study on electric utility generating capacity.[10] The information was gathered from Edison Electric Institute, Federal Power Commission, large manufacturers, and Electric World. Resulting projections made to the year 1980 give the following results.

Federal Power Commission	430 million kilowatts
Ebasco Services, Inc.	540 million kilowatts
Edison Electric Institute	570 million kilowatts
Electric World	630 million kilowatts
Large Manufacturers	700 million kilowatts

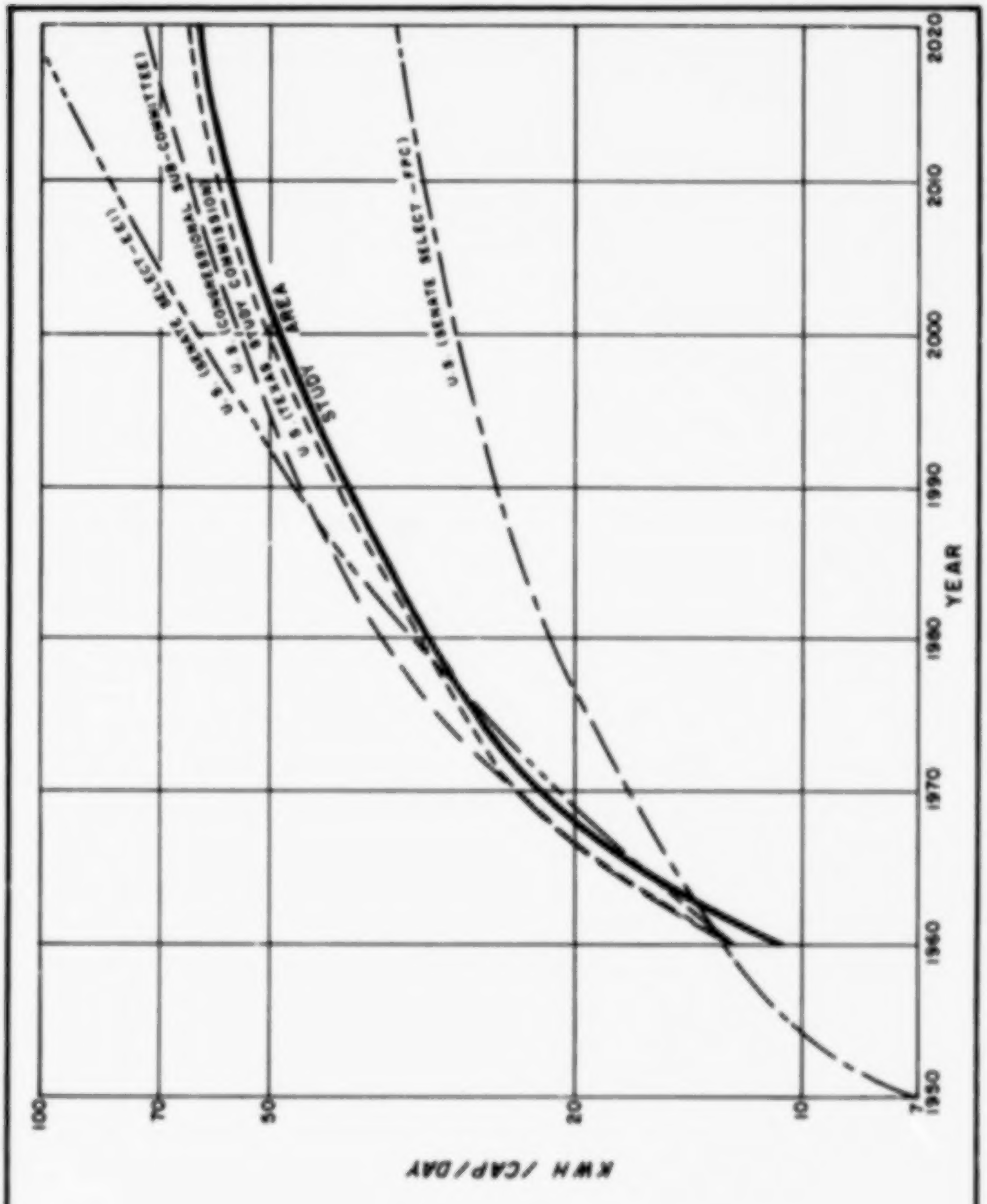
This study was also used as a guide to projections in the Arkansas-Red River basins study area.

The Federal Power Commission's kilowatt-hour per capita predictions made for the U.S. Study Commission-Texas indicate its thoughts that the per capita energy requirements for this area exceed those for the country as a whole. The Nation shows a 1950-60 trend of 10 percent increase as compared to a 38 percent rise in this region. It is anticipated that the growth will continue at a high rate for the next 10- and possibly 20-year period and then progress at about the same rate as the Nation as a whole.

Historical trends would establish similar projections, with this study below that of the U.S. Study Commission-Texas study area. This is due to the greater industrial area along the Gulf Coast. In the U.S. Study Commission-Texas report,[9] the Federal Power Commission's extrapolated figure for the year 2020 shows 63.5 kilowatt-hours per capita as against the projected study area figure of 62.7 kilowatt-hour per capita. See Figure I-17.

Petroleum Refining

As discussed in previous sections of this report, the petroleum industry in the Arkansas-Red River basins has been a significant factor in the growth of the region. This influence is expected to continue for some time in future years, though to a lesser extent. In 1960, the study area contained about 6.4 billion barrels of proved recoverable crude oil reserves. This amounted to almost 17 percent of the Nation's estimated recoverable crude oil supply. Projection of the Nation's growing demand for fuels (for heat and power production) and other petroleum products indicates that



ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

POWER REQUIREMENT
PROJECTIONS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE I-17

annual crude oil consumption will increase threefold within the next 40 to 50 years. 11/ Total U.S. Crude oil production in 1960 amounted to about 2.9 billion barrels. 12/ At this rate of production, the known recoverable U.S. reserves (38 billion barrels) would be depleted in 13 years if no new additions were made to the present supply. The 13-year figure has also applied in past years, indicating that the yearly increase in reserves has just been keeping pace with production.

It is generally understood among oil experts 13/ that, sooner or later, an oil producing area will reach a peak in production and will start a gradual decline in production with the constant drop-off slowed to some extent by advanced methods of secondary recovery. Eventually, the field will be nonproductive, as many are today. It is believed that many fields in the Arkansas-Red River basins (one of the oldest producing regions in the Nation) have passed the point of maximum productivity and will eventually be depleted. However, for the petroleum industry to continue to grow and meet the Nation's demands for petroleum products, new sources of crude must be found for industry in the study area as well as other parts of the Nation.

Several possibilities exist for supplementing present crude oil supplies to meet future demands. They are:

1. New methods of secondary recovery may make possible nearly 100 percent recovery of the oil and gas potential of a field. 13/ Such methods, if applicable to all types of oil producing formations, would double our present known recoverable reserves which are based on 50 percent recovery.

2. Development of oil shales in the Colorado River basin is expected to provide a major source of crude oil supply. 14/ Known reserves of shale oil in the Rocky Mountain area have been estimated at about 900 billion barrels by the Geological Survey.

3. Oil experts believe large reserves will be located with further exploration of the Continental Shelf area of Louisiana and California and the new State of Alaska.

4. By the year 2000, about 50 percent of the crude processed in this country may be imported from other areas of the world. 7/

5. Estimates of total economically recoverable petroleum and oil-shale resources of the U.S. and the free world are given in the following table.

Table I-4

Current International
Petroleum and Oil-Shale Resources
(billions of barrels)

	Liquid Hydrocarbons	Shale Oil
United States	170	2,000+
Rest of Free World	730	2,000+
TOTAL	900	4,000+

Source: U.S. Congress [14]

As local reserves in the basins are depleted, refineries may obtain crude from sources listed above. Crude from the Colorado River basin could be distributed throughout the basins through the vast system of oil and gas pipelines now established, and future lines. Crude petroleum may also be brought in by barge [15] from other regions.

Current petroleum refining in the study area is expected to increase about fourfold from approximately 0.8 billion bbl/day in 1960 to 3.2 billion bbl/day in 2020 to help meet the expected increase in national demands for petroleum products. The major oil refining centers in the study area are expected to remain essentially the same. Projected petroleum refinery output in barrels per day is given for expected future refining centers in Table I-5.

Table I-5

Petroleum Refining in the Arkansas-Red River Basins Study Area, Present and Projected Production

(bbl/day)

Map Designation	General Area of Expansion	Present Refining Capacity	Approx.* 1960 Production	Projected 2020 Production
Kansas				
K-7	McPherson	31,000	24,800	92,500
K-8	Wichita-El Dorado	153,250	122,500	465,000
K-11	Neodesha	31,490	25,200	143,000
K-12	Coffeyville	24,500	19,500	111,000
Oklahoma				
O-4	Enid	31,680	25,300	95,300
O-5	Ponca City	107,000	85,500	320,600
O-6	Tulsa	124,000	99,200	375,000
O-7	Cushing	36,920	29,500	121,000
O-9	Duncan-Wynnewood	80,000	64,000	242,000
O-12	Grandfield	7,200	5,760	22,100
O-13	Ardmore	25,000	20,000	76,700
O-15	Okmulgee	19,000	15,200	86,000
Texas				
T-1	Sunray	25,000	20,000	76,800
T-2	Amarillo	19,000	15,200	57,400
T-3	Phillips	71,000	56,800	216,000
T-8	Wichita Falls	20,800	16,700	63,900
T-11	Gainesville	2,000	1,600	6,390
T-12	Dallas-Ft. Worth	11,400	9,130	51,200
T-16	Mt. Pleasant	19,000	15,200	86,000
T-18	Longview	10,300	8,240	47,600
Arkansas				
A-11	El Dorado	80,400	64,300	360,000
Louisiana				
L-1	Shreveport	17,500	14,000	79,600
		947,440	757,630	3,195,090

* Estimated 80 percent of capacity - the national average for 1960.

Source: World Oil 12/, and The Oil and Gas Journal 16/

Petrochemical Production

Much of the past economic growth of the Arkansas-Red River basins, and the Nation as well, has been attributed to development of natural resources (petroleum and natural gas in particular). With the development of these resources and considerable progress in technological know-how spurred on by increased demands for new and better fibers, materials, detergents, fertilizers, fuels, etc., the petrochemical* industry developed. Petrochemicals, which use as feedstock by-products from petroleum refineries and natural gas processing plants, were expected to account for about 30 percent of all chemical production in 1960. 17/ This amounts to about 56 billion pounds. The value of these petrochemicals was expected to approach $6.9 billion or 61 percent of the total value of all chemicals.

The most favorable conditions for location of a petrochemical plant according to industry experts 17/ are those such as afforded the Gulf Coast petrochemical complex which has been hailed as an "Industrial Cinderella," since about 85 percent of the U.S. industry is within 400 miles of New Orleans. 18/ These conditions are:

1. Nearby a readily available supply of raw materials from refineries and gas fields.
2. A plentiful supply of cheap natural gas for fuel.
3. Ample supplies of salt. (Many of the major petrochemical producers have located their plant next to salt domes, a trend that is becoming more pronounced. There are 300 salt domes between southwestern Alabama and the lower tip of Texas. The industry is currently converting resources of the salt domes into a rapidly growing number of products.) 18/
4. Ample supplies of fresh water.
5. Ample supplies of sulfur and lime.

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*Petrochemicals - Chemical compounds or chemical elements recovered in whole or in part from petroleum or natural gas and intended as raw materials for the chemical processing industry. 19 20/

6. Ready access to water transportation for the plant products either by ocean going tanker or river barge (access to market).

7. Also, many of these plants are dependent on other plants for interchange of raw materials and by-products, so there tends to be a snowballing effect.

While all of the above conditions are not prevalent (to a significant degree, in any one area in the Arkansas-Red River basins region, the basins are expected to supply their own demands for petrochemicals and be competitive to outside markets in some products. Large-scale productive units and combinations are expected to supply chief agricultural areas with sufficient demands for fertilizers and insecticides.

Petrochemical production in the Arkansas-Red River basins in 1960 accounted for about 9 percent (approximately 5 billion pounds)[17] of the total U.S. production. That the industry has experienced a rapid growth in the basins is pointed up by the increase in number of plants from 2 to over 45 since 1940. [17, 21]

To determine future growth of this industry in the basins, consideration was given to future national demands and that portion of the demand which might be satisfied by the petrochemical industry in the basins.

As a basis for projecting national growth of this industry, the following general assumptions were made:

1. The petrochemical industry is reaching maturity and future growth rates will approach the Gross National Product (GNP) rate. [17] (For projection purposes the rate of 3.75 percent, compounded annually, as projected in the Senate Select Committee Print No. 5 [22] was used. Current trends indicate that the industry growth rate, which is currently about 10 percent [17] and dropping, will level out near the GNP rate about 1975.)

2. Ratios between the petrochemical groups aliphatics, aromatics, and inorganics will be approximately the same as the ratios projected by the Oil and Gas Journal [17] through the year 1965.

3. Ethylene is expected to remain one of the leading aliphatic petrochemicals and the assumption is made that the future production ratio of ethylene to total aliphatics will be approximately the same as the ratio projected by the Oil and Gas Journal [17] for 1965. (Although there is a feeling among some in the chemical industry that other aliphatics may someday replace part of the ethylene market, there is no basis for forecasting a change in the near future and the percent of reduction in the ethylene market cannot be foreseen.)

4. The future production ratios of ammonia, carbon black, and sulfur to the total inorganic production are expected to approximate present ratios.

5. The principal petrochemicals - polyethylene, ethyl alcohol, ethylene oxide, and ethylene dichloride - produced from ethylene are expected to have future production ratios to total ethylene production comparable to present ratios. (This assumption is made with the follwoing limitation: Should the automotive industry go to more permanent antifreezes, the demand for ethylene glycol would drop off unless other uses can be found for this product. If this happens, the demand for ethylene oxide - from which ethylene glycol is derived - may drop off.) [23]

In prorating national petrochemical growth to the Arkansas-Red River basins, it appears that the major opportunity for expansion in the basins is in the utilization of ethane and natural gas as feedstock and in the production of the inorganic petrochemical, ammonia, and the aliphatic petrochemicals forecasted for the area by the Department of Commerce report, Location Factors in the Petrochemical Industry. [22] The major types of petrochemicals which appear to be more favorable than other chemicals for production in the study area are:

Ethylene Glycol
Acrylonitrile
Hydrogen Cyanide
Ethanolamines
Ethylene Oxide
Acetic Anhydride
Acetic Acid
Acetaldehyde
Ethyl Alcohol
Formaldehyde
Methanol
Polyvinyl Acetate
Polyvinyl Chloride
Vinyl Acetate
Vinyl Chloride
Urea
Polyethylene
Ethylene Dichloride
Methyl Chloride
Ethylene
Acetylene

In determining the types of chemicals as well as the percent of national petrochemicals that might originate in the study area, the methodology utilized in the comprehensive study 22/ by the Department of Commerce was adopted. The procedures adhered to by the study included the following considerations.

1. Regional availability of raw materials.
2. Regional cost differentials in petrochemical production.
3. Regional transport cost differentials.
4. Economies of scale (plant capacity).

As indicated in the study, petrochemical production in the basins is expected to be limited to low tonnage chemicals (except in a few areas which will have access to water transportation). 13/

The petrochemical manufacturing centers in the study area are expected to remain essentially the same with the possible addition of a few areas such as Garden City, Kansas, which has access to needed feedstock from large nearby gas fields and agricultural markets for fertilizers in Kansas.

The areas of expected petrochemical expansion and the percent of total basin expansion expected to originate in these areas are given in Table I-6.

Table I-6

Projected 2020 Petrochemical Production in the Arkansas-Red River Basins

Area	% of Basin Expansion	Yearly Prod. (million lbs.)
Monroe, Louisiana	14	5,428
Shreveport, Louisiana	13	5,040
Amarillo, Pampa, Borger, Texas	13	5,040
Longview, Marshall, Texas	13	5,040
Ponca City, Tulsa, Oklahoma	12.5	4,846
Wichita, Kansas	12.0	4,652
El Dorado, Arkansas	11.0	4,265
Garden City, Kansas	8.0	3,102
Wichita Falls, Texas	3.5	1,357

It should be pointed out that there are many influencing factors which are difficult to predict in projecting future growth of the petrochemical industry. Company initiative in deriving new production techniques, new chemical processes, and finding new uses for petrochemical feedstock cannot be predicted. Political controls on feedstock (oil and gas production) are also difficult to forecast. Any number of unpredictable factors could affect the accuracy of such projections.

Natural Gas Processing

As discussed in Volume I of this Appendix, a large portion of the United States gas reserves and gas processing industry is within the Arkansas-Red River basins. While the gas industry in the basins appears to be firmly implanted, several factors should be pointed out in regard to long range projections of future growth in the region.

The national rate of consumption is increasing faster than the increase in reserves. In 1957, the demand was 11.3 trillion cubic feet and the reserve increase was 20.1 trillion cubic feet. 24/ In 1960, the demand was 13 trillion cubic feet and the increase in reserves was 10.8 trillion cubic feet. 24/ The national reserve total January 1, 1961, was 273.37 trillion cubic feet (a 21-year supply with present consumption rates). 24/

Since the trend of gas discoveries is downward and the trend of gas consumption is upward, there is presently some concern over the future of this industry. If this trend continues, expansion may be curtailed in a very few years. Since pipelines and distribution systems are financed on 20-year bonds, reserves must always assure at least a 20-year supply. 25/ If supply fails before the facilities are amortized, the bonds will not pay out.

The peak in U.S. gas reserves is expected around 1980. 24 25/ Conservative estimates indicate the total U.S. reserve will reach around 425 trillion cubic feet with annual consumption increasing to about 20 trillion cubic feet by this time.

Several factors improve an otherwise uncertain outlook in the study area for the gas processing industry and petrochemical plants utilizing natural gas as feedstock. They are:

1. As pointed out in the discussion on petroleum refining, new methods of secondary recovery may make possible a much greater recovery of the gas potential of a field. 13/

2. Future progress in obtaining a high quality gas from coal may make available for local fuel and feedstock use much of the gas reserve in the Arkansas-Red River basins which is committed to the large fuel industry in the East. 21/

3. The large network of gas lines from most of the major fields in the eight states partially included in the basins pass through the region on their way to markets in the East. As reserves are depleted, industries in the Arkansas-White-Red area could obtain gas from these sources. In 1960, the eight states partially included in the basins held 95 percent of all the U.S. gas reserves. 26/

4. Another factor which is of major significance to the petrochemical industry is the small demand the petrochemical industry has on natural gas production. (In 1960, the demand on crude oil and natural gas was only 2 percent of the combined production of these industries. 20/

In projecting future growth of the gas processing industry in the Arkansas-Red River basins, it is assumed that the rate of expansion through the year 1980 will approximate the growth projected in Senate Select Committee Print No. 8. 7/ The expected increase for the period is 53 percent over the 1954 level. As indicated in Print No. 8, production after 1980 is expected to level out and remain at about the same level. The present major gas processing areas in the basins are expected to remain the leading areas in the future with principal expansion in the natural gas processing industry directed toward increased plant output and efficiency. Present gas processing centers and 1960 plant outputs and capacities are shown in Table I-7.

Table I-7

Natural Gas Processing in the Arkansas-Red River Basins Study Area--1960

Map Designation	General Area of Expansion	Present Capacity (mil. cf/d)	Processed in 1960 (mil. cf/d)
Kansas			
K-1	Ulysses	1,605	1,234
K-4	Medicine Lodge	60	--
K-8	Wichita	120	118
K-9	Attica	55	44
Oklahoma			
0-1	Hooker	692	387
0-2b	Elk City	285	266
0-3		28	28
0-4	Covington	50	21
0-5	Blackwell	302	260
0-6		62	36
0-7	Chandler	109	65
0-8	Oklahoma City	245	82
0-9	Lindsay	807	551
0-13	Healdton	103	88
0-14		86	61
0-20		15	15
Texas			
T-1	Sunray	2,170	793
	Dumas		
T-2	Amarillo	200	66
T-3	Pampa-Borger	1,404	478
T-4b		24	24
T-7	Knox City	18	16
T-8		16	7
T-9	Graham	23	22
T-10	Springtown	459	287
T-11		41	29
T-14		54	--
T-15	Van	46	17
T-17		30	25
T-18	Longview-Marshall	509	308
T-19	Carthage	1,292	892
Arkansas			
A-9	Stamps	58	53
A-10	Magnolia	350	252
A-11	El Dorado	31	16
Louisiana			
L-1	Cotton Valley	549	264
L-2	Ruston	248	152
L-3	Monroe	325	325
L-4	Waterproof	154	136
TOTAL		12,625	7,418

Source: The Oil and Gas Journal 27/

Pulp and Paper Manufacture

The study area now accounts for about 5 percent of the total U.S. pulpwood consumption. This trend is expected to continue in future years. Extrapolation of projections made by the Forest Service [28] to 2010 indicates the U.S. pulpwood consumption in 2020 will be approximately 160 million cords. Assuming that the study area will continue to meet about 5 percent of the Nation's demand, the 2020 study area output will be 8 million cords.

The area of softwood forests was estimated by multiplying the area of commercial forests by a ratio $\frac{\text{volume of softwood growing stock,}}{\text{volume of total growing stock,}}$ developed from tabulated data for each subarea. The Forest Service indicates that some forests can produce 1.25 cords of softwood per acre of forest with controlled forestry practices. [28] By assuming an average 2020 production of 0.60 cord per acre of softwood forest, there will be sufficient pulpwood to meet projected demands.

This (0.6 cord/acre) rate of production was applied to the area of softwood forest and the projected production of pulpwood summarized by subareas.

Future paper mills were generally located considering pulpwood availability, barge transportation (existing and proposed), and sufficient supply of appropriate quality water.

Pulp and paper production in the study area is given in Table I-8 under present (1959) conditions and as expected in 2020.

Table I-8

Present and Projected Pulp and Paper Production in the Study Area--1959 and 2020

Map Designation	Commercial Forests Area 1,000 Acres Total	Commercial Forests Area 1,000 Acres Estimated Softwood	Pulpwood Production Cords Per Day Actual 1959	Pulpwood Production Cords Per Day Projected 2020	Paper Mill Capacity No. of Plants/Tons Per Day Actual 1958	Paper Mill Capacity No. of Plants/Tons Per Day Projected 2020
Oklahoma						
O-16	149	5	24	8	1/90	1/90
O-17	983	74	-0.1	121		
O-19a	1,410	1,190	20	1,950		1/700
O-19b	1,920	1,070	60	1,760		2/1,400
Texas						
T-12					1/40	1/40
T-15	244	164	10	270		
T-16	649	113	64	186		
T-17	661	164	120	270		
T-18	465	216	164	356		1/800
T-19	631	306	147	504		
Arkansas						
A-2	1,707	178	-0.4	293		
A-3	3,595	1,920	202	3,150		1/2,000
A-4	138	45	0	74		
A-5	2,055	1,420	451	2,330		
A-6	371	257	43	421		
A-7	565	232	82	381	2/880	3/944
A-8	1,169	68	5	112		
A-9	1,951	1,200	423	1,970		
A-10	650	354	246	582		
A-11	955	503	452	828	1/600	2/1,220
A-12	1,745	1,020	860	1,680		
A-13	1,516	670	460	1,100	1/655	1/655
Louisiana						
L-1	905	312	354	512	2/1,480	2/1,480
L-2	3,717	2,080	1,960	3,430	1/580	1/580
L-3	627	168	185	277	2/1,725	2/1,725
L-4	2,149	76	166	125		
L-5	623	316	202	518		
L-6	645	226	144	373		1/500

Source: Forest Service 29-33/

Primary Metals Output

Iron and Steel

As discussed in Volume I of this Appendix, the iron and steel industry in the Arkansas-Red River basins is largely centered at two locations:[34] (1) the Colorado Fuel and Iron plant at Pueblo, Colorado, and (2) the Lone Star Steel plant at Lone Star, Texas. A small number of iron and steel operations are also located at other points in the basins. These installations, however, are much smaller and less diversified, and do not appear to have the potential necessary for becoming large iron and steel complexes such as those mentioned.

Because of this, future growth of the iron and steel industry within the basins is expected to be centered largely at the two established locations; however, cognizance should be given to the area of bituminous coal reserves in southeastern Oklahoma as a possible future location for limited iron and steel production. Located in Sequoyah, Haskell, and LeFlore Counties, the fields are within easy reach of the authorized Arkansas navigation project. An industry locating in this area would have access to needed coking coal and economical water transportation.[35]

Several observations and assumptions are made regarding future growth of the iron and steel industry, both in the study area and throughout the Nation:

1. As evidenced by present iron ore production, the increasing ratio of crude to usable ore and the extent of U.S. reserves,[36] within the next sixty years the U.S. iron and steel industry will have to depend on foreign imports for most of its crude ore. As this trend develops, industry is expected to tend toward market orientation, locating near the coast and/or inland waterways.

   The east Texas steel industry, currently using coal from southeastern Oklahoma, and the Colorado industry are undergoing considerable expansion and becoming fully diversified. As these industries, which are located at opposite ends of the basins grow, they are expected to meet most of the basin demands. Increased demands for steel in central and northern Oklahoma may, however, result in the location of a small plant on the Arkansas near these growing market areas.

2. The future annual rate of growth or expansion for the industry presently in the basins will approximate the projected national iron and steel annual expansion rate which are:

   (1) Steel ingot production -- 2 percent
   (2) Pig iron production -- 1 percent

   The influence of aluminum, plastics, fiber glass, and other materials on steel demand is expected to be greater in future years than it has been in the past. While such an influence is unpredictable, some consideration should be given in projecting future demands for steel products. The historical rate of increase in steel production since 1915 has been about 2¼ percent, compounded yearly. 36/ Notwithstanding encroachments of other materials in heavy steel-using industries such as, the automotive and building construction industries, the future growth of the steel industry is expected to continue in a similar fashion to the historical trend. As a basis for projecting future demands, it is assumed that steel production will increase at about 2 percent per year, a slight change from past trends due to expected influence from the other material industries.

3. Advanced technology in the dressing of iron ores will make possible the use of large quantities of low grade ores.

Present and projected production for principal iron and steel industries within the study area is given in Table I-9.

Table I-9

Present and Projected Production for Principal Iron and Steel Industries in the Study Area

Location	Present Production (Yearly)	2020 Production (Yearly)
Pueblo, Colorado	1.3 million tons	4.26 million tons
Lone Star, Texas	0.8 million tons	2.62 million tons

Source: Pueblo Chamber of Commerce 37/, Pueblo Planning Commission 38/, and Standard and Poors Corporation Records 39/

Aluminum

Aluminum is produced at two locations in the study area, both in central Arkansas, near the Nation's most productive bauxite reserve. In 1959, over 95 percent of the U.S. bauxite production was produced from deposits near Little Rock and Bauxite, Arkansas. 36/ Alumina reduction plants located near Arkadelphia and Jones Mills, Arkansas, presently account for about 7 percent of the Nation's aluminum production when operating near capacity. 36/

In evaluating the future growth potential for the aluminum industry in the study area, several factors must be considered. The Arkansas bauxite deposit is not homogeneous and therefore varies in value as aluminum feedstock. Only about 50 million tons of high quality bauxite remain in the deposit. 19/ At current production rates this deposit will last between 30 and 40 years. Supplies could however, be supplemented by overseas deposits since completion of the Arkansas River navigation canal will make available water shipment within 40 miles of present alumina reduction plants.

While the availability of water shipment may help maintain the present level of production, little expansion above this level is expected in the area due to the large electric power demands needed in the reduction of alumina.

The largest cost item involved in the smeltering of aluminum is electric power. Approximately 10 kilowatt-hours of electric power are required to produce a pound of aluminum. 40/ At an average of approximately 2 mills per kilowatt-hours, the percentage of net plant costs per pound of aluminum for power is from 16 - 21 percent. 40/ Since electric power costs, bauxite extraction costs, and transportation of alumina to smelter constitute most of the cost in producing aluminum, future expansion of the industry is expected to occur in areas where large quantities of cheap hydroelectric power are available, such as Canada and Alaska or in coastal areas such as the Gulf which are nearer to the principal sources of alumina (overseas deposits) and natural gas or some other form of fuel which can be used to produce thermoelectric power. In the latter case, the high cost for electric power is offset some by lower transportation costs.

In view of the high costs of power available for aluminum smelting in the study area and expected depletion of usable bauxite reserves, the study area aluminum production in the year 2020 is expected to remain near the present level. Projected 2020 production is therefore 150,000 short tons per year (about 90 percent of capacity).*

---

* The U.S. aluminum industry averaged 86 percent in 1959. 36/

Agriculture

Since the principal agricultural water use in the study area is for crop irrigation, specific agricultural projections are confined to irrigation. Irrigation projections are derived from an examination of irrigated lands, irrigable lands, irrigated acreage projected to the year 2020, and future agricultural efficiencies.

The basis for analyzing variations in agricultural production and irrigation water requirements are type-of-farming areas developed from classifications used by the Bureau of the Census. These farming areas, shown in Figure I-18, are based on: (1) type of crops; (2) type of livestock programs; (3) rainfall, and (4) length of growing season. Table I-10 tabulates the number of commercial farms by product or crop.

Irrigation projections for the study area are founded on information developed for the Senate Select Committee by the U.S. Department of Agriculture. 41/ The findings of this Committee base projected irrigation needs on a projected per capita requirement for food and fiber and the projected high, medium, and low 1980 and 2000 national populations. From these data, the U.S. Department of Agriculture ascertained agricultural acreage, both dryland and irrigated, needed to satisfy the projected total demand for food and fiber, also taking into consideration future imports and exports. National acreages then were allocated to dryland and irrigated land needed in each major river basin.

Curry County, New Mexico and Parmer, Castro, Floyd, and Hale Counties, Texas, are deleted in the irrigation study to conform to the river basin subdivisions used in Senate Select Committee projections (see Figure I-18). Although portions of these counties are within the Red River basin, inclusion of the extensive irrigated acreages in these counties (almost 1½ million acres in 1959) would inflate the study area base for projection and result in distortion of the anticipated basin share of national irrigation expectations. The Arkansas-Red River basins study area, thus adjusted, is approximately the same as the Upper and Lower Arkansas-White-Red basins, and expected growth rates for this part of the U.S. total is deemed applicable to the study area.

The Senate Select Committee's year 2000 irrigation projection for the medium population, geometrically extrapolated to 2020, indicates irrigation acreage will increase approximately 100 percent in the Upper Arkansas-White-Red River area, and 350 percent in the Lower Arkansas-White-Red River area. Farming areas 1 through 7 are designated as the Upper study area; and the remaining, 8 through 11, make up the Lower study area.

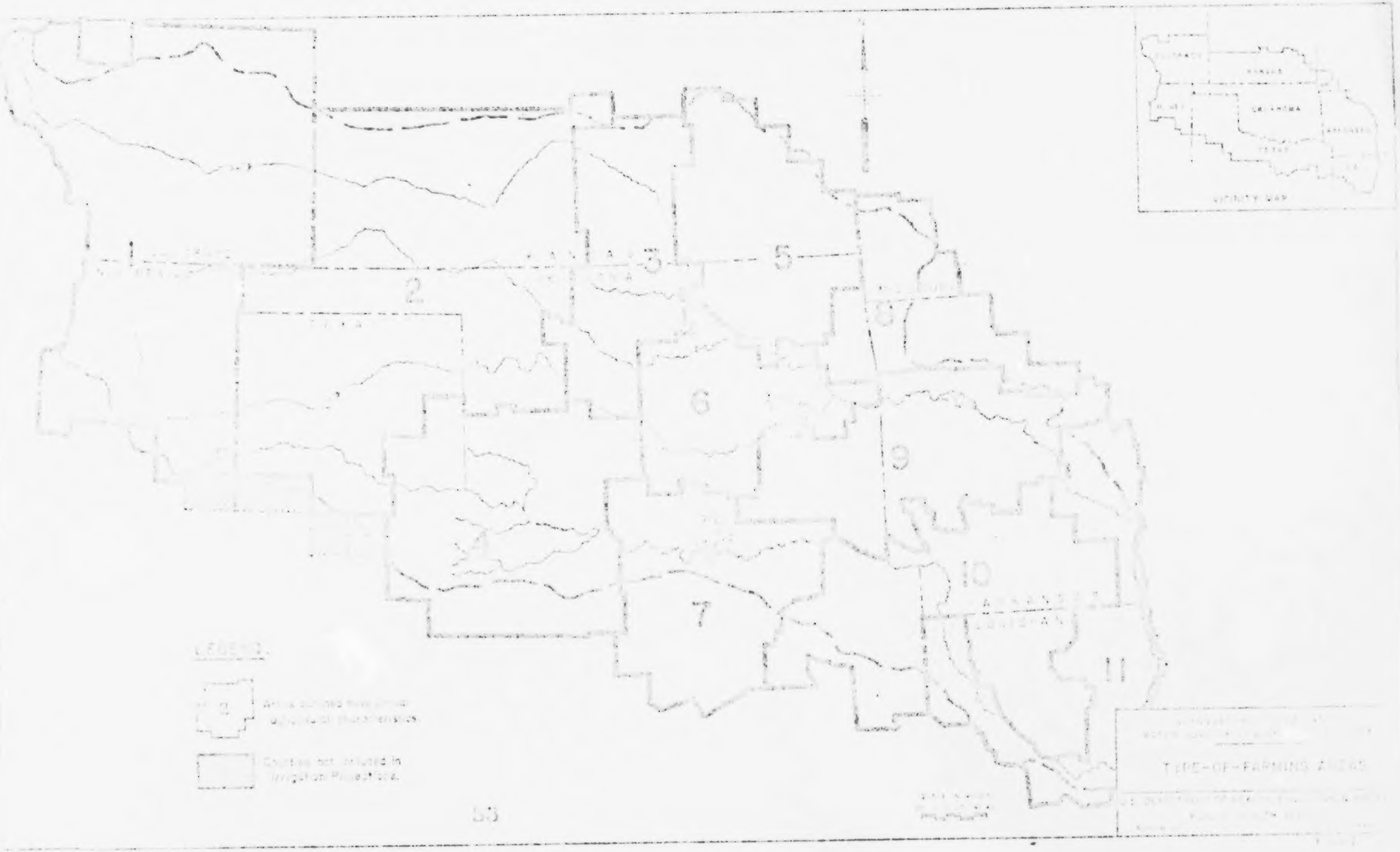

VICINITY MAP
COLORADO
KANSAS
OKLAHOMA
TEXAS
ARKANSAS
1
2
3
4
5
6
7
8
9
10
11
KANSAS
OKLAHOMA
TEXAS
MISSOURI
ARKANSAS
LOUISIANA
LEGEND
2
Areas outlined have similar agricultural characteristics.
Counties not included in Irrigation Projections.
TYPE-OF-FARMING AREAS
U.S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
PUBLIC HEALTH SERVICE

Table I-10

Type of Farms by Type-of-Farming Area--1959
(Number of Farms)

Type-of-Farming Area	Cash Grain	Cotton	Other Field Crops	Vege-tables	Fruit & Nuts	Poultry	Dairy	Live-stock Farms	Live-stock Ranches	General	Misc.
1	2,359	21	206	92	21	185	469	5,166	3,084	876	3,168
2	15,651	834	94	17	--	166	667	8,668	1,721	1,420	3,808
3	14,976	131	---	30	--	157	1,265	4,656	353	1,724	4,647
4	2,986	8,874	546	5	--	164	662	5,326	2,243	2,866	5,950
5	5,538	26	---	50	--	242	2,235	9,347	807	375	11,521
6	933	700	425	61	--	193	1,425	7,040	2,252	1,340	13,996
7	1,245	6,196	483	66	--	520	2,010	8,254	3,100	1,870	16,903
8	1,487	70	45	68	440	3,060	5,406	5,733	232	951	17,270
9	644	1,115	248	146	412	1,445	1,285	5,187	1,203	603	18,964
10	169	3,547	671	271	88	1,325	1,429	6,043	1,901	664	21,609
11	2,126	14,091	219	50	27	327	572	2,771	491	627	14,402
Total	48,114	35,605	2,937	856	988	7,784	17,425	68,191	17,387	13,316	132,238

Source: Bureau of the Census 42/

Irrigation projections for the study area appear in Table I-11.

Table I-11

Past and Projected Irrigation in the Study Area and the U.S.
(1,000 Acres)

	1944	1949	1954	1959	2020
Upper Study Area	694	1,113	1,466	2,564	2,932
Lower Study Area	169	249	514	440	2,310
TOTAL	863	1,362	1,980	3,004	5,242
U.S.	20,539	25,905	29,552	33,211	71,000

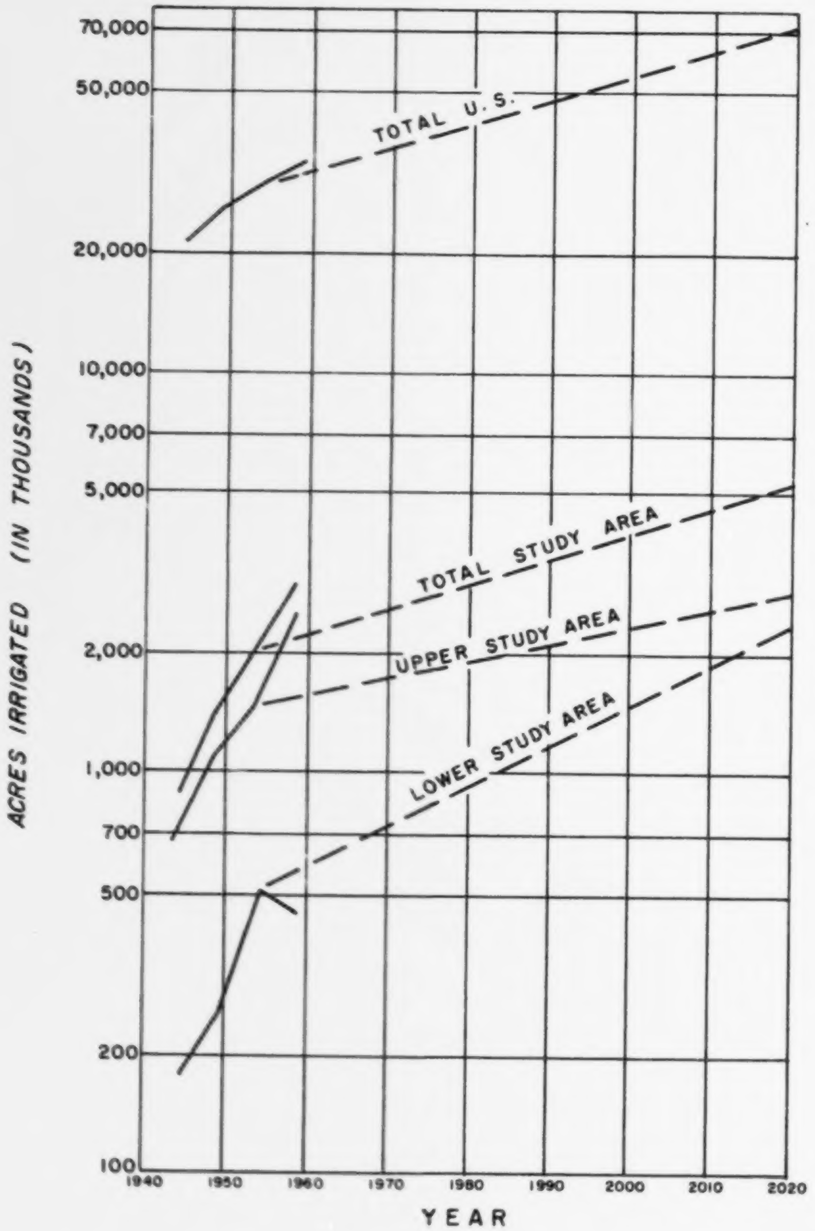
Source: Bureau of the Census 42 43/

Irrigation projections presented in Table I-11 and depicted on Figure I-19, use 1954 irrigated acreages as a projection base. Data for 1959 are also included for comparison purposes. Examination of historic trends in Figure I-19 show that irrigated acreage projected growth rates of the Senate Select Committee were exceeded during the period 1954-59 for both the U.S. and the study area.

Rapid increases during this five-year period in the Upper study area were due primarily to the extensive development of ground water irrigation in the High Plains region. This trend cannot be expected to continue indefinitely, since ground water is currently being mined in much of this area, especially in the southern High Plains. 44/

The Lower study area declined in acres irrigated from 1954 to 1959. This downward trend probably reflects the relatively high rainfall and its fortuitous distribution in 1959, as compared with 1954. Over a period of time, supplemental irrigation is expected to increase substantially in the Lower study area. This practice tends to stabilize the farm economy and allows the irrigator to make more efficient use of seed, fertilizers, equipment, and labor with more consistent and usually larger harvests. 45/

Study area irrigation acreage projection allocation to each farming area are the result of careful consideration of: past and present irrigation, lands suitable for irrigation, water quality suitable for irrigation, surface water quantity available for irrigation, and ground water reserves. Significant portions of these data are summarized in Table I-12.



ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

IRRIGATION TRENDS & PROJECTIONS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE I-19

Table I-12

Type-of-Farming Area Irrigation Data
(1,000 Acres)

Type-of-Farming Area	Acres Irrigated						Irrigable Lands
				1959			
	1944	1949	1954	Surface	Ground	Total	
1	534	572	401	511	78	589	2,220
2	148	496	916	50	1,617	1,667	7,160
3	---	1	16	3	24	27	340
4	10	41	110	52	207	259	325
5	---	---	6	3	1	4	110
6	---	1	7	3	3	6	190
7	1	1	8	8	4	12	150
8	---	1	8	3	1	4	200
9	---	1	19	11	2	13	400
10	3	13	36	7	14	21	1,100
11	166	234	451	94	308	402	1,720
Total*	862	1,361	1,978	745	2,259	3,004	13,915

* Totals may not agree with Table I-11 because of rounding.

Source: Bureau of the Census 42 43/, and Bureau of Reclamation and Soil Conservation Service 46/

The irrigable lands data in Table I-12 for the Reclamation States include all lands suitable for irrigation, regardless of the quality or quantity of water available. These acreages are based on tabulations made by the Bureau of Reclamation for the Arkansas-White-Red River basins report of 1955. Irrigable lands data for Arkansas and Louisiana are based on tabulations made by the Soil Conservation Service.

Ratios of 1959 acreages irrigated from surface supplies to the total lands irrigated are used to establish the aggregate amount of land that will be irrigated from surface sources, except in those areas where ground water is limited, or being depleted. For the latter, future ground water irrigation considers estimated rates of recharge. Acreages to be irrigated by ground water are projected only to the limit recharge (adjusted for projected municipal and industrial withdrawals) can sustain. Two areas of severe ground water depletion are the southern High Plains of Texas and the Grand Prairie region of Arkansas. However, sufficient ground water is available in other parts of the same farming area to replace acreages forced out of production by exhaustion of local water supply.

Expectations are that, except for those projects presently constructed or firmly committed, 47/ all surface irrigation will be performed by individuals irrigating through streambank pump plants. Firmly committed reservoirs containing irrigation storage are: Foss, Canton, and Cobb Reservoirs in western Oklahoma, and Bayou Rapides and Bayou Beouf Reservoirs in Louisiana. The Frying Pan-Arkansas River project located near Pueblo, Colorado, will not increase present acreages, but it is intended to permit more efficient irrigation of existing acreages.

Estimation of acreages to be irrigated from surface sources in each type-of-farming area by individual watersheds results from consideration of quality and quantity of water available in each stream. First consideration is given to irrigable lands along streams which in 2020 are assumed to have a sufficient quantity of good quality water available for irrigation.

Projected study area irrigated acreage requirements for 2020 by expected source of water supply and type-of-farming areas, considering the above factors and limitations, is presented in Table I-13.

Table I-13

2020 Study Area Irrigation by Source

Type-of-Farming Area	1,000 Acres Surface	Ground	Total
1	510	90	600
2	60	1,653	1,713
3	18	132	150
4	70	200	270
5	31	17	48
6	48	37	85
7	43	23	66
8	108	30	138
9	232	41	273
10	178	357	535
11	864	500	1,364

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II. EXISTING WATER USES

Present Water Use

Water used by human beings for drinking and other domestic purposes is conceded to be the most essential use of water. Such water is generally given the primary procurement rights and afforded the highest degree of quality protection, but other beneficial uses may have water quality criteria that are far more stringent in certain aspects than waters used for drinking. The following discussion examines three such uses from the standpoint of quantity and quality requirements as related to the Arkansas-Red River basins study area.

Municipal Water Use

Quantity

Municipal water withdrawals throughout the Nation in 1960 amounted to about 8 percent of the total water withdrawn. 1/ Though small in relation to industrial and agricultural water needs, municipal requirements are by far the most variable in both locale and type of use.

Included in municipal water uses are demands exerted for lawn sprinkling, car washing, street washing, fire fighting, ice making, air conditioning, food preparation, recreation, manufacturing (cooling and process water), waste conveyance, and countless others. As further pointed out in a succeeding section of this chapter, overall unit municipal water demand is best expressed in terms of gallons per capita day (gpcd). This rate of use includes not only water used for residential and public purposes, but that supplied to light industrial and commercial installations directly related to the increasing demands for goods and services by the local population.

Based on weighted average (by population served) data from 27 of the major cities in the study area, mean annual unit municipal water demand increased from 115 gpcd to about 125 gpcd from 1950 through 1959. Though fluctuations occurred through the 10-year period, these trends give definite indications of increasing unit demands. Total municipal water use in the study area in 1960 averaged almost one billion gallons per day. This is about 3 percent of the Nation's estimated total municipal water demand. 1-3/ Tabular data on quantity and quality of individual study area public water supplies are presented in Table II-1.

Table II-1

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/l)			
		Surface Water		Ground Water					
		Source	Yield (mgd)	Source	Yield (mgd)	Cl⁻	$SO_4^=$	Hardness (as $CaCO_3$)	DS
Colorado									
C-1									
Pueblo									
Pueblo	26.30	Arkansas R.	50.00	6 Wells		6	115	174	285
El Paso									
Colorado Spgs.	19.20	Bear & Fountain Crs. Blue R.	42.36			9	17	60	111
Manitou Spgs.	1.10	French & Ruxton Crs.				2	7	16	56
TOTAL	46.60		92.36						
Colorado									
C-2									
Elbert									
Lincoln									
Limon	0.75			7 Wells	9.86	13	116	461	1,090
Kit Carson									
Burlington	0.30			4 Wells	2.90	6	18	138	235
Cheyenne									
Cheyenne Wells	0.12			4 Wells	1.44	1	13	132	307
Kiowa									
Eads	0.05			3 Wells	1.40	47	353	356	1,150
Prowers									
Lamar	0.85			20 Wells	9.30	9	193	276	452
Holly	0.13			4 Wells	1.10	13	172	250	650
Baca									
Springfield	0.23			3 Wells	3.20	9	200	302	685
TOTAL	2.40				29.20				
Colorado									
C-3									
Huerfano									
Walsenburg	3.50	Cucharas R.	2.00			0	13	97	413
Custer									
Fremont									
Canon City	3.00	Arkansas R.	2.53			3	20	95	130
Florence		Newlin Cr.	1.13e			0	15	123	166
Chaffee									
Salida	1.50	S. Ark. R.	2.00	4 Wells		2	16	153	215
Buena Vista	0.20	Cottonwood Cr.	1.30	1 Well		0	4	40	57
Lake									
Leadville	2.00	Evans & Iowa Cr.	2.00			8	18	17	88
Park									
Teller									
TOTAL	10.20		10.93						
Colorado									
C-4									
Las Animas									
Trinidad	6.00	Purgatoire R. & Whiskey Cr.	8.00			1	6	76	98
Aguilar	0.05			Wells	0.05	3	10	193	286
Otero									
La Junta	2.70			10 Wells	10.00	46	871	848	1,660
Rocky Ford	2.00	Arkansas R.	2.30	7 Wells		38	700	808	1,640
Fowler	0.01			3 Springs	0.06	180	432	306	1,160
Crowley									
Ordway	0.20			2 Wells	0.20				
Bent									
Las Animas	0.43			4 Wells	3.40	100	1,520	1,140	2,830
TOTAL	11.39		10.30		13.71				

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/l)			
		Surface Water		Ground Water				Hardness	
		Source	Yield (mgd)	Source	Yield (mgd)	Cl^-	$SO_4^=$	(as $CaCO_3$)	DS
New Mexico									
NM-1									
Colfax									
Raton	0.90	Lake Maloya	4.00			2	30	96	173
Springer	0.10	Eagle Nest Lake	0.30			6	167	272	410
Mora									
San Miguel									
Las Vegas	1.20	Gallinas R.	1.85	6 Wells	1.37				
TOTAL	2.20		6.15		1.37				
New Mexico									
NM-2									
Union									
Clayton	0.60			7 Wells	1.25	16	46	275	383
Harding									
Quay									
Tucumcari	1.10			13 Wells	2.74	8	13	200	272
Curry									
Clovis	3.20			14 Wells	10.50	16	27	170	276
TOTAL	4.90				14.49				
Kansas									
K-1									
Greeley									
Tribune	0.25			Wells	0.88e	7	12	160	207
Wichita									
Leoti	0.10			Well	1.00e	10	19	150	246
Scott									
Scott City	0.46			Well	2.70e	17	40	190	343
Lane									
Dighton	0.23			Wells	1.30e	36	42	325	459
Hamilton									
Syracuse	0.25			Well	0.70e	4	79	176	305
Kearney									
Lakin	0.07			Wells	1.15e	9	30	160	236
Finney									
Garden City	2.00			Wells	5.25	28	109	246	530
Stanton									
Grant									
Ulysses	0.40			Wells	3.00e	26	137	196	442
Haskell									
Sublette	0.10			Wells	0.70e	10	46	150	263
Morton									
Elkhart	0.25			Wells	0.90e	20	89	288	426
Stevens									
Hugoton	1.50			Wells	2.90e	26	164	324	521
Seward									
Liberal	2.90			Wells	4.30e	15	86	230	363
TOTAL	8.33				25.06				
Kansas									
K-2									
Ness									
Ness	0.20			Wells	1.13e	37	137	370	580
Rush									
LaCrosse	0.15			Wells	1.27e	385	223	62	1,232
Pawnee									
Larned	1.30			Wells	3.95	77	662	680	1,272
TOTAL	1.65				6.35				

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/l)			
		Surface Water		Ground Water					
		Source	Yield (mgd)	Source	Yield (mgd)	Cl^-	$SO_4^=$	Hardness (as $CaCO_3$)	DS
Kansas									
K-3									
Hodgeman									
Jetmore	0.22			Wells	0.76e	58	141	446	687
Gray									
Cimarron	0.55			Wells	0.40	9	35	160	261
Ford									
Dodge City	1.50			Wells	4.05	17	70	238	353
TOTAL	2.27				5.21				
Kansas									
K-4									
Meade									
Meade	0.50			Well	1.80e	8	18	150	224
Clark									
Ashland	0.50			Wells	1.85e	34	342	564	805
Comanche									
Coldwater	0.15			Wells	0.80e	9	7	130	195
Barber									
Medicine Lodge	0.06			Wells	1.20e	16	33	194	274
Kiowa	0.18			Wells	1.90e	99	185	442	790
TOTAL	1.39				7.55				
Kansas									
K-5									
Edwards									
Kinsley	0.30			Wells	1.73	4	11	126	178
Kiowa									
Greensburg	0.25			Wells	2.00e	8	12	219	256
Pratt									
Pratt	1.60			Wells	6.40e	51	22	196	308
Stafford									
Stafford	0.20			Wells	1.08	113	15	214	432
St. John	0.22			Wells	2.25	29	17	184	298
Rice									
Sterling	0.50			Wells	1.15	93	88	260	548
Lyons	0.75			Wells	2.75	165	59	274	637
TOTAL	3.82				17.36				
Kansas									
K-6									
Barton									
Holsington	0.53			Wells	5.04	75	35	120	339
Ellinwood	0.42			Wells	1.30	92	635	642	1,305
Great Bend	2.75			Wells	9.94	149	164	298	699
TOTAL	3.70				16.28				
Kansas									
K-7									
Ellsworth									
Wilson	0.20			Wells	0.40e	62	66	344	578
Ellsworth	0.25			Wells	1.00e	118	179	135	536
McPherson									
McPherson	2.00			Wells	5.90	20	10	256	340
Lindsborg	0.38			Wells	2.90	79	159	488	753
Marion									
Peabody	0.15			Wells	0.43e	38	438	710	1,042
Marion	0.30	Mud Cr.	1.00e			153	843	1,099	1,563
Hillsboro	0.16			Wells	0.44e	65	1,386	1,670	2,360
Harvey									
Newton	2.50			Wells	2.50	11	22	150	242
Halstead	0.17			Wells	1.62	26	28	150	317
Sedgwick	0.10			Wells	0.85	46	130	454	622
Hesston	0.04			Wells	0.94e	42	35	250	514
TOTAL	6.25		1.00		16.98				

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/l)			
		Surface Water		Ground Water					
		Source	Yield (mgd)	Source	Yield (mgd)	Cl^-	$SO_4^=$	Hardness (as $CaCO_3$)	DS
Kansas									
K-8									
Cowley									
Arkansas City	1.50			Wells	4.32e	530	170	426	1,404
Winfield	1.60			Wells	3.89e	530	65	736	1,184
Butler									
Augusta	0.35	Impounded Res.	1.03e	Wells		330	233	186	983
El Dorado	0.75	Impounded Res.	2.46e	Wells		336	244	116	979
Sedgwick									
Wichita	28.75			88 Wells	88.00e	23	29	144	292
Haysville				Wells		147	162	134	519
Derby				Wells	0.07e	59	109	404	600
Reno									
Nickerson	0.10			Wells	0.90	249	295	408	1,162
Hutchinson	7.00			12 Wells	18.00e	168	130	334	751
TOTAL	40.05		3.49		115.18				
Kansas									
K-9									
Sumner									
Wellington	0.75	Impounded Res.	2.80e	Well		87	115	354	552
Caldwell	0.22			Wells	0.50e	31	62	276	390
Belle Plaine	0.14			Well	1.20e	25	20	156	287
Harper									
Anthony	0.50			Wells	1.22e	30	61	254	465
Harper	0.38			Wells	1.55e	22	18	184	315
Kingman									
Kingman	0.55			Spring & Wells	1.08e	13	13	112	206
TOTAL	2.54		2.80		5.55				
Kansas									
K-10									
Chautauqua									
Sedan	0.15	Impounded Res.				10	26	114	150
Elk									
Howard	0.08	Impounded Res.	0.28e			10	26	120	171
Greenwood									
Eureka	0.35	Lake Eureka & Fall R.	0.35e			57	39	247	360
Madison	0.08			Wells	0.36e	23	27	379	455
Chase									
Cottonwood Falls	0.09			Wells	0.20e	17	70	216	539
Morris									
Council Grove	0.40	City Lake & Neosho R.	1.30e			8	38	132	184
TOTAL	1.15		1.93		0.56				
Kansas									
K-11									
Lyon									
Emporia	3.00	Neosho R. & Lake Kahola	4.50e			12	37	64	126
Coffey									
Burlington	0.10	Neosho R.	0.83e			103	107	288	567
Woodson									
Yates Center	0.20	Impounded Res.	0.69e			95	38	122	289
Allen									
Iola	0.70	Neosho R.	2.07e			22	71	62	183
Humbolt	0.25	Neosho R.	0.94e			25	66	154	260
Wilson									
Neodesha	0.50	Fall R. (imp.)	1.73e			47	31	300	338
Fredonia	0.50	Fall R. (imp.)	1.55e			85	51	156	700
Neosho									
Chanute	1.40	Neosho R.	3.14e			88	47	112	296
Erie	0.04	Neosho R.	0.62e	Well		34	80	100	255
Labette									
Parsons	2.00	Labette Cr. & Neosho R.	5.18e			8	92	193	397
Oswego	0.20	Neosho R.	0.96e			40	51	130	247
Chetopa	0.10	Neosho R.	0.52e			30	154	226	383

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/l)			
		Surface Water		Ground Water				Hardness	
		Source	Yield (mgd)	Source	Yield (mgd)	Cl^-	$SO_4^=$	(as $CaCO_3$)	DS
Kansas									
K-11 (Continued)									
Cherokee									
Galena	0.35			Wells		12	61	224	282
Columbus	0.35			Wells	0.65e	71	70	218	548
Baxter Spring	0.05			Wells	1.00e	81	75	228	419
TOTAL	9.74		22.73		1.65				
Kansas									
K-12									
Montgomery									
Independence	1.50	Elk & Verdigris Rs. (imp.)	3.45e			120	40	250	300
Coffeyville	3.00	Verdigris R. (imp.)	6.84e			105	48	288	508
Cherryvale	0.25	Verdigris R.	1.38e			95	40	104	291
Caney	0.30	L. Caney R.	0.69e			150	23	220	530
TOTAL	5.05		12.36						
Kansas									
K-13									
Crawford									
Arma	0.04			Wells	0.30e	225	57	260	776
Pittsburg	1.60			Wells	3.11e	87	80	297	531
Girard	0.25			1 Well	1.35e	523	124	455	1,287
Frontenac	0.20			Wells	0.86e	112	36	218	491
TOTAL	2.09				5.62				
Oklahoma									
O-1									
Cimarron									
Boise	0.34			4 Wells	1.57	26	63	226	324
Texas									
Guymon	0.90			8 Wells	4.94	8	77	239	331
Hooker	0.10			4 Wells	1.20	34	135	308	457
Texhoma	0.88			3 Wells	0.18	14	48	208	318
Beaver									
Beaver	0.30			3 Wells	0.94	55	51	234	413
Harper									
Buffalo	0.30			Wells & Springs	0.50	43	72	276	453
Laverne	0.30			3 Wells	1.60	52	114	350	556
TOTAL	3.12				10.93				
Oklahoma									
O-2a									
Ellis									
Shattuck	0.28			5 Wells	1.60	12	11	230	296
Woodward									
Woodward	1.20			36 Wells	5.20	26	23	107	197
Dewey									
Blaine									
Geary	0.14			5 Wells	2.00	64	200	350	783
O'Keene	0.18			3 Wells	0.54	46	59	240	449
Watonga	0.60			6 Wells	3.00	25	74	302	462
TOTAL	2.40				12.34				
Oklahoma									
O-2b									
Roger Mills									
Cheyenne	0.08			4 Wells	0.22	6	11	230	350
Custer									
Clinton	1.20	Lake Clinton	1.00	20 Wells	2.20	11	10	172	251
Thomas	0.08			6 Wells	0.18	26	183	350	618
Weatherford	0.40			15 Wells	1.50	3	6	116	179
Beckham									
Elk City	0.90			16 Wells	2.60	38	118	328	519
Erick	0.05			6 Wells	1.00	38	413	656	994
Sayre	0.50			12 Wells	2.59	14	192	430	591
Washita									
Cordell	0.55	Lake Cordell	0.30	15 Wells	1.60	10	7	129	187
Sentinel	0.10			5 Wells	0.54	35	224	488	740
Harmon									
Hollis	0.50			3 Wells & 2 Springs	0.58	14	54	250	410

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/l)			
		Surface Water		Ground Water				Hardness	
		Source	Yield (mgd)	Source	Yield (mgd)	Cl^-	$SO_4^=$	(as $CaCO_3$)	DS
Oklahoma									
0-2b (Continued)									
Greer									
Mangum	0.70			13 Wells	1.19	20	16	142	265
Granite	0.10			4 Wells	0.37	12	20	210	360
Kiowa									
Hobart	0.69	Lake Hobart	2.30	11 Wells		16	57	208	306
Snyder	0.25	Lake Snyder	0.50	5 Wells		6	17	51	90
Mountain View	0.10			10 Wells	0.25	11	17	228	341
TOTAL	6.20		4.10		14.82				
Oklahoma									
0-3									
Woods									
Alva	1.00			18 Wells	3.25	8	11	134	197
Waynoka	0.20			7 Wells	1.45	17	35	216	335
Alfalfa									
Cherokee	0.75			7 Wells	4.50	86	63	312	515
Grant									
Medford	0.17			7 Wells	1.40	76	76	313	688
Major									
Fairview	0.32			5 Wells	1.44	17	16	209	283
TOTAL	2.44				12.04				
Oklahoma									
0-4									
Garfield									
Enid	3.80			84 Wells	14.50	60	26	182	379
TOTAL	3.80				14.50				
Oklahoma									
0-5									
Kay									
Ponca City	8.00	Lake Ponca	15.00	63 Wells	20.00	32	30	180	268
Tonkawa	0.20			12 Wells	1.00	16	216	423	644
Newkirk	0.35	Lake Newkirk	0.30e	4 Wells		8	36	134	181
Blackwell	2.50	Lake Blackwell							
		Chikaskia R.	3.00e			37	108	256	402
TOTAL	11.05		18.30		21.00				
Oklahoma									
0-6									
Osage									
Pawhuska	1.25	Lake Pawhuska	1.25			5	13	133	156
Hominy	0.30	Lake Hominy	0.22			7	8	116	154
Fairfax	0.29	Lake Fairfax	1.00e			5	13	137	183
Barnsdall	0.17	Lake Barnsdall	0.50e			22	21	147	213
Creek									
Sapulpa	0.90	3 Impoundments	2.00			31	50	98	181
Oilton	0.02			9 Wells	0.03	135	91	318	653
Drumright	0.45			11 Wells	1.50	8	63	208	300
Bristow	0.25			19 Wells	0.82	54	44	314	457
Washington									
Dewey	0.39	Caney R.	0.50e			114	30	264	504
Bartlesville	3.00	Lake Hudson							
		Lake Hulah	15.00			9	20	69	105
Tulsa									
Skiatook		Tulsa							
Sand Springs	1.00	Shell Cr. Lake	3.00e			22	22	56	117
Jenks	0.10			2 Wells	0.20	33	58	317	410
Collinsville	0.18	Caney R.							
		Horseshoe Lake	1.30e			122	38	280	538
Broken Arrow	0.43			10 Wells	0.75	8	4	41	119
Bixby	0.15			4 Wells	0.29	18	5	53	135
Tulsa	32.80	Lake Spavinaw	100.00						
		Grand R.	32.00			5	6	91	114
TOTAL	41.68		156.77		3.59				
Oklahoma									
0-7									
Noble									
Perry	0.60	Lake Perry	1.80			6	10	62	107
Pawnee									
Pawnee	0.35	Lake Pawnee	1.10	3 Wells		7	18	152	201
Cleveland	0.21	Lake Cleveland	0.48e			9	9	68	164

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/l)			
		Surface Water		Ground Water				Hardness	
		Source	Yield (mgd)	Source	Yield (mgd)	Cl^-	$SO_4^=$	(as $CaCO_3$)	DS
Oklahoma									
0-7 (Continued)									
Kingfisher									
Kingfisher	0.20			4 Wells	4.32	66	87	272	543
Hennessey	0.20			4 Wells	0.55	250	25	424	825
Logan									
Guthrie	0.80	Lake Liberty Lake Guthrie	2.25			15	18	199	231
Crescent	0.15			3 Wells		112	54	400	642
Payne									
Yale	0.10			5 Wells	0.40	28	27	213	321
Stillwater	2.80	Lake Carl Blackwell, Lake Boomer	10.00			39	26	112	197
Cushing	2.00	Lake Cushing	2.98	9 Wells	1.31	24	11	124	175
Lincoln									
Stroud	0.17			9 Wells	0.39				
Prague	0.15			8 Wells	0.26	11	29	12	409
Chandler	0.15	Lake Chandler	0.83			20	32	552	612
TOTAL	7.88		19.44		7.23				
Oklahoma									
0-8									
Canadian									
El Reno	1.50			14 Wells	7.60	115	188	127	534
Yukon	0.16			6 Wells	5.58	66	138	505	807
Oklahoma									
Oklahoma City	30.12	N. Canadian R.	46.00	105 Wells	31.00	73	64	90	262
Edmond	1.00			10 Wells	4.00	150	68	82	712
Del City	1.00			12 Wells	1.50	8	6	192	230
Bethany	0.90			7 Wells	4.20	28	91	264	416
Midwest City	1.70			23 Wells	5.00	6	7	110	200
Nichols Hills	1.50			18 Wells	4.00	50	65	20	642
Warr Acres		Oklahoma City							
Village		Oklahoma City							
Cleveland									
Norman	1.80			20 Wells	3.80	13	96	8	550
Lexington	0.07			1 Well	0.36	42	84	398	574
Moore	0.06			2 Wells	0.25	7	6	222	279
TOTAL	39.81		46.00		67.29				
Oklahoma									
0-9									
McClain									
Purcell	0.48	Purcell Lake	0.86e	13 Wells		61	136	531	726
Blanchard	0.10			13 Wells	0.13	14	28	384	434
Caddo									
Anadarko	0.75	Washita R.		5 Wells	2.30	64	348	488	806
Apache	0.06			6 Wells	0.54	7	12	254	296
Carnegie	0.13			10 Wells	0.87	9	25	279	379
Cement	0.10			5 Wells	0.24	1,160	201	1,290	3,160
Cyril	0.13			6 Wells	0.28	11	78	300	407
Hinton	0.06			4 Wells	0.20	16	13	192	347
Grady									
Rush Springs	0.20			2 Wells	1.30	23	77	288	407
Minco	0.10			3 Wells	0.43	3	15	220	272
Chickasha	1.50	Washita R. (imp.)	5.50e			79	529	748	1,180
Garvin									
Wynnewood	0.25			10 Wells	0.88	147	166	476	1,040
Lindsay	0.32			9 Wells	1.90	25	130	621	723
Maysville	0.15			5 Wells	0.72	38	69	590	731
Pauls Valley	0.90	Washington Cr. & Lake Pauls Valley	2.83e	5 Wells	Standby	76	136	824	976
Stephens									
Marlow	0.25			18 Wells	1.30	127	84	266	522
Duncan	2.00	Duncan & Chisholm Trail Lakes	3.00			6	102	222	280
Comanche	0.20	Lake Comanche	0.44e			8	3	104	137
Sulphur	0.75			6 Wells	1.86	5	16	330	344
Davis	0.17			5 Wells	0.33	82	38	388	646
TOTAL	8.60		12.63		13.28				

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/l)			
		Surface Water		Ground Water				Hardness	
		Source	Yield (mgd)	Source	Yield (mgd)	Cl$^-$	SO$_4^=$	(as CaCO$_3$)	DS
Oklahoma									
0-10									
Comanche									
Lawton	9.00	Lakes Lawtonka & Elmer Thomas	11.00			10	19	144	175
Cache	0.05			2 Wells	0.18e	7	21	97	161
TOTAL	9.05		11.00		0.18				
Oklahoma									
0-11									
Jackson									
Altus	3.06	Lake Lugert	7.00e			215	522	606	1,230
El Dorado	0.05			4 Wells	0.18	109	949	1,260	1,840
TOTAL	3.11		7.00		0.18				
Oklahoma									
0-12									
Tillman									
Tipton	0.13			2 Wells	0.24	148	93	316	748
Grandfield	0.13			22 Wells	0.60	7	12	184	252
Frederick	0.60			16 Wells	2.00	69	52	214	536
Cotton									
Temple	0.16	Cache Cr.		9 Wells	0.20	84	65	326	672
Walters	0.28	Boyer Res.	1.65	4 Wells	0.29	96	117	379	930
Jefferson									
Waurika	0.27			21 Wells	0.55	170	77	364	902
Ryan	0.13			17 Wells	0.46	52	58	448	631
Ringling	0.09			3 Wells	0.13	18	66	3	675
Love									
Marietta	0.11			2 Wells	0.43	13	45	48	427
TOTAL	1.90		1.65		4.90				
Oklahoma									
0-13									
Carter									
Wilson	0.09			3 Wells		21	111	214	524
Healdton	0.18			6 Wells	0.48e	139	15	12	1,060
Ardmore	3.50	Mountain and City Lakes	6.00e	8 Wells		8	22	148	181
TOTAL	3.77		6.00		0.48				
Oklahoma									
0-14									
Coal									
Coalgate	0.13			5 Wells	0.17	32	36	6	386
Lehigh	0.04			5 Wells		70	256	304	644
Pontotoc									
Allen	0.08			1 Well	0.09	505	24	16	1,600
Ada	4.00			1 Spring	6.60	5	8	362	357
Pottawatomie									
Tecumseh	0.25	Lake Tecumseh	0.50e			9	11	66	97
Shawnee	2.00	Shawnee Res.	10.00			11	25	74	108
Seminole									
Wewoka	0.75	Wewoka Lake	0.80			8	3	41	46
Seminole	1.00			19 Wells	2.00	4	47	124	244
Maud	0.25			5 Wells		136	372	16	1,640
Konowa	0.20			3 Wells	2.00	81	57	498	676
Okfuskee									
Weleetka	0.08	Grassy Lake	0.36e			9	10	37	91
Okemah	0.36			2 Wells	1.00	250	35	434	830
Boley	0.05			3 Wells	0.10	12	8	221	263
McIntosh									
Eufaula	0.23			2 Wells	0.72e	9	20	189	246
Checotah	0.20	Lake Checotah	1.10e			2	13	39	62
Hughes									
Wetumka	0.12	Lake Wetumka	0.25e			9	14	59	108
Holdenville	0.70	Holdenville Lake	4.00			4	9	47	68
TOTAL	10.44		17.01		12.68				

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/l)			
		Surface Water		Ground Water					
		Source	Yield (mgd)	Source	Yield (mgd)	Cl^-	$SO_4^=$	Hardness (as $CaCO_3$)	TDS
Oklahoma									
0-15									
Okmulgee									
Okmulgee	3.00	Salt Cr. & Lake Okmulgee	7.00			56	12	63	166
Morris	0.13	Morris Lake	0.25e			15	81	83	182
Henryetta	1.00	Henryetta Lake & Wolfe Cr.	3.00			7	39	67	99
Dewar		Henryetta							
Beggs	0.13	Beggs Lake	0.25e			75	16	66	219
Muskogee									
Muskogee	8.00	Ft. Gibson Res.	50.00			48	12	88	137
Haskell	0.05			27 Wells	0.10e	9	3	40	133
Ft. Gibson	0.19	Grand R.	0.50e			15	55	167	228
Boynton	0.04	Boynton Lake	0.14e			14	63	66	179
TOTAL	12.54		61.14		0.10				
Oklahoma									
0-16									
Nowata									
Nowata	0.36	Verdigris R.	4.00			172	58	351	666
Craig									
Vinita	1.20	Neosho R. & Grand Lake	4.50e			12	58	170	227
Rogers									
Claremore	0.61	Lake Claremore	1.36			4	17	50	115
Chelsea	0.13	Chelsea Lake	0.16e			3	45	121	156
Mayes									
Pryor		Grand R. Dam				11	55	166	223
Wagoner									
Wagoner	0.50	Ft. Gibson Res.	1.50e			22	54	164	221
Coweta	0.07	Lake	0.10	7 Wells		8	4	47	97
TOTAL	2.87		11.60						
Oklahoma									
0-17									
Cherokee									
Tahlequah	0.80	Illinois R.	1.50e			6	5	87	115
Adair									
Stillwell	0.40			Springs	0.86	6	4	120	147
Delaware									
Grove	0.07	Grand Lake	0.29e			12	55	170	226
Jay	0.12	Brush Cr.	0.21e			9	3	138	182
Ottawa									
Quapaw	0.20			Well	0.50	4	18	130	152
Picher	0.23			3 Wells	0.52	16	16	130	170
Miami	1.20			6 Wells	4.32	42	15	135	217
Commerce	0.30			2 Wells	0.50	8	16	123	159
Afton	0.08			2 Wells	1.08	348	18	172	758
TOTAL	3.40		2.00		7.78				
Oklahoma									
0-18									
Pittsburg									
McAlester	2.00	Lake McAlester	7.00			5	28	45	74
Quinton	0.10	Quinton Lake	0.14e			10	8	19	59
Krebs	0.15	Krebs Lake				2	5	18	33
Hartshorne	0.33	Lake Hartshorne	1.00e			3	4	37	45
Haileyville		Hartshorne							
TOTAL	2.58		8.14						
Oklahoma									
0-19a									
Sequoyah									
Vian	0.08	Vian Lake	0.12e			3	8	22	46
Sallisaw	0.15	Big Sallisaw Cr.	0.20			4	10	70	90
Muldrow	0.05	Pond	0.25e			7	66	37	153

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/l)			
		Surface Water		Ground Water				Hardness	
		Source	Yield (mgd)	Source	Yield (mgd)	Cl^-	$SO_4^=$	(as $CaCO_3$)	DS
Oklahoma									
0-19a (Continued)									
Haskell									
Stigler	0.26	Lake Stigler	1.44e	Wells		5	6	19	43
Latimer									
Wilburton	0.35	Cumneo Tubby Cr. Fourche Maline Cr.	0.80e			9	9	20	62
LeFlore									
Talihina	0.16	Lake Talihina	0.50e			7	7	18	52
Spiro	0.35	Lake Spiro	0.46e	4 Wells		9	20	41	100
Poteau	0.37	Poteau R.	2.10e			6	8	37	73
Heavener	0.25	Black Fork Cr.	0.40e			6	5	14	41
Panama	0.10	Poteau R.	0.11e			16	224	150	623
Arkoma		Fort Smith, Ark.							
TOTAL	2.12		6.38						
Oklahoma									
0-19b									
Pushmataha									
Antlers	0.16	Kiamichi R.	0.15			6	7	17	65
Choctaw									
Hugo	0.50			6 Wells	2.00e	5	22	252	312
Boswell	0.05			3 Wells	0.07	83	70	394	621
McCurtain									
Idabel	0.50	Little R.	0.45			9	4	21	67
Broken Bow	0.03	Broken Bow Res.	165.00			3	2	44	64
TOTAL	1.24		165.60		2.07				
Oklahoma									
0-20									
Johnston									
Tishomingo	0.40	Pennington Lake	2.50e	Spring		4	4	258	248
Marshall									
Madill	0.20	Carter Lake & Madill City Lake	0.40			6	5	73	100
Atoka									
Atoka	0.50	Atoka & Katy Lakes	0.50			24	26	116	189
Bryan									
Durant	1.60	Blue R.	5.00			10	55	267	312
Caddo	0.05			4 Wells	0.08	20	32	2	503
TOTAL	2.75		8.40		0.08				
Texas									
T-1									
Oldham									
Hartley									
Dallam									
Dalhart	0.80			8 Wells	4.00	13	44	214	327
Sherman									
Stratford	0.30			3 Wells	1.23	14	44	213	304
Moore									
Dumas	1.10			8 Wells	5.02	9	29	204	267
Sunray	0.28			2 Wells	2.10	14	25	210	275
Hansford									
Spearman	0.50			4 Wells	2.80e	15	47	225	313
Ochiltree									
Perryton	1.20			6 Wells	5.18e	52	36	235	380
TOTAL	4.18				20.33				
Texas									
T-2									
Potter									
Amarillo	17.10			90 Wells	70.00	13	34	244	364
Randall									
Amarillo (See Potter Co.)									
Canyon	1.00			10 Wells	5.00	35	35	112	413
TOTAL	18.10				75.00				

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/1)			
		Surface Water		Ground Water				Hardness	
		Source	Yield (mgd)	Source	Yield (mgd)	Cl^-	$SO_4^=$	(as $CaCO_3$)	DS
Texas									
T-3									
Hutchinson									
Borger	2.20			15 Wells	16.20	17	97	202	330
Stinnet	0.50			Well	0.90	10	27	238	280
Carson									
White Deer	0.21			3 Wells		13	16	190	285
Panhandle	0.23			12 Wells	1.20	21	26	244	360
Gray									
McLean	0.50			3 Wells	1.10	25	18	213	308
Pampa	6.00			15 Wells	13.00e	82	101	227	532
TOTAL	9.64				32.40				
Texas									
T-4a									
Lipscomb									
Roberts									
Hemphill									
Canadian	0.78			5 Wells	1.30	100	34	246	495
TOTAL	0.78				1.30				
Texas									
T-4b									
Wheeler									
Shamrock	1.20			Springs	5.00	20	63	254	366
Armstrong									
Claude	0.10			4 Wells		14	28	250	354
Donley									
Clarendon	0.50			Wells	2.00e	25	21	263	351
Collingsworth									
Wellington	0.25			6 Wells	0.72	36	108	310	530
Briscoe									
Silverton	0.15			4 Wells	0.79	14	18	278	339
Hall									
Memphis	0.30			25 Wells	1.20	16	18	225	304
Childress									
Childress	1.10	Lake Childress	2.00	14 Wells	1.00	40	306	378	481
TOTAL	3.60		2.00		10.71				
Texas									
T-5									
Deaf Smith									
Hereford	1.80			9 Wells	7.78	28	170	390	574
Parmer									
Bovina	0.31			2 Wells	0.81				
Friona	0.44			Wells	1.65	31	30	221	288
Farwell	0.21			2 Wells	0.90	16	27	172	276
Castro									
Dimmit	0.75			4 Wells	2.60				
Swisher									
Tulia	0.88			6 Wells	2.90e	26	25	208	363
Floyd									
Floydada	0.50			4 Wells	2.50	36	57	257	430
Lockney	0.33			Wells	1.80	36	36	250	461
TOTAL	5.22				20.94				
Texas									
T-6									
Hale									
Hale Center	0.25			2 Wells	1.50e	18	26	237	345
Plainview	4.00			9 Wells	10.30	24	30	252	366
Abernathy	0.41			5 Wells	3.30	34	24	260	384
TOTAL	4.66				15.10				
Texas									
T-7									
Motley									
Matador	0.23			4 Wells	0.50	167	139	395	1,042
Cottle									
Paducah	0.21			9 Wells	0.70	23	151	305	463

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/l)			
		Surface Water		Ground Water					
		Source	Yield (mgd)	Source	Yield (mgd)	Cl^-	$SO_4^=$	Hardness (as $CaCO_3$)	DS
Texas									
T-7 (Continued)									
Hardeman									
Chillicothe	0.20			5 Wells		11	28	213	295
Quanah	0.60			11 Wells	2.30	132	315	550	892
Wilberger									
Vernon	1.30			38 Wells	2.60	24	28	248	342
Foard									
Crowell	0.20			8 Wells	0.70	29	131	320	450
Dickens									
Spur	0.31			Wells	1.50	302	476	550	1,566
King									
Knox									
Munday	0.40			3 Wells	1.30	395	400	40	1,950
Knox City	0.30			Well	1.00	205	211	490	1,212
Baylor									
Seymour	0.45			12 Wells	2.50e	79	76	309	551
Stonewall									
Aspermont	0.18			3 Wells	0.40	53	71	250	564
Haskell									
Rule	0.21			4 Wells	0.76	67	46	298	540
Haskell	1.00			18 Wells	2.10	160	126	365	912
Throckmorton	0.15	Lake Throckmorton	0.50			44	18	150	241
TOTAL	5.74		0.50		16.36				
Texas									
T-8									
Wichita									
Electra	0.18	China Cr.				18	29	263	468
Iowa Park	0.20	Lake Iowa	1.20			152	159	277	637
Burkburnett	0.50			48 Wells	1.40	46	40	274	465
Wichita Falls	11.50	Lake Wichita & Holliday Cr.	22.00			29	16	100	183
TOTAL	12.38		23.20		1.40				
Texas									
T-9									
Archer									
Archer City	0.20	Impounded Lake	0.54e			25	48	133	297
Holliday	0.06	Impounded Lake	0.25e			56	41	198	321
Clay									
Henrietta	0.25	Lake Wichita	0.65e			227	23	161	600
Young									
New Castle	0.04	Lake	0.03			11	78	108	248
Olney	0.53	Lake	1.50e			122	13	124	352
Graham	1.08	Reservoir	2.50e			42	14	62	139
Jack									
Jacksboro	0.29			Wells	0.75e	22	26	196	290
TOTAL	2.43		5.47		0.75				
Texas									
T-10									
Montague									
Bowie	0.40	Lake Amon Carter	2.80			17	20	103	160
Nocona	0.30			13 Wells	0.60	16	37	8	436
Saint Jo	0.10			3 Wells	0.24	153	56	137	740
Wise									
Decatur	0.30			8 Wells	0.61	44	26	58	387
Bridgeport	0.23	W. Fork Trinity	0.58e			18	71	156	230
Parker									
Weatherford	0.95	Impounded Lake	4.50e			8	16	133	178
TOTAL	2.28		7.88		1.45				
Texas									
T-11									
Cooke									
Gainesville	2.00			8 Wells	3.50	45	34	8	513
Muenster	0.12			3 Wells	0.25	19	38	10	420

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/l)			
		Surface Water		Ground Water					
		Source	Yield (mgd)	Source	Yield (mgd)	Cl⁻	$SO_4^=$	Hardness (as $CaCO_3$)	DS
Texas									
T-11 (Continued)									
Grayson									
Whitesboro				Wells		80	39	9	581
Van Alstyne				2 Wells		32	76	4	546
Whitewright	0.11			2 Wells	0.39e	64	111	111	762
Denison	3.50	Red R., Shawnee Cr., Lake Texoma	4.00e			169	115	144	507
Sherman	4.00			12 Wells	4.60	136	86	9	776
TOTAL	9.73		4.00		8.74				
Texas									
T-12									
Denton									
Sanger	0.10			4 Wells	0.25	11	68	5	592
Pilot Point	0.18			3 Wells	0.14	21	89	7	550
Denton	3.00	Lewisville Res.	4.00	11 Wells	10.00	45	31	65	177
Lewisville	0.16			3 Wells	0.45	143	210	56	1,335
Collin									
Celina				2 Wells		32	58	7	596
Tarrant									
Fort Worth	46.00	W. Fork Trinity	57.00			22	20	139	208
Arlington	3.85	Lake Arlington	4.00	12 Wells	5.00	20	32	42	132
Grapevine	0.27			3 Wells	0.55	145	221	15	1,152
White Settlement	0.77			14 Wells		13	48	210	364
Lake Worth	0.13			3 Wells	0.23	48	150	9	798
River Oaks	0.78	Lake Worth	1.99e			23	19	140	205
Sansom Park	0.18			7 Wells	0.50	14	60	7	521
Westworth				Wells					
Halton City	2.00			Wells	4.00	103	160	11	960
Hurst	0.40			4 Wells	0.55	22	88	7	606
N. Richland Hills				Wells					
Richland Hills	1.40			9 Wells	2.80	85	128	9	780
Dallas									
Irving	1.30	Dallas		8 Wells		100	170	24	868
Grand Prairie		Dallas		8 Wells	9.00	85	169	51	870
Lancaster				3 Wells	1.80	177	228	19	1,200
Seagoville		Dallas Aux.		2 Wells	0.70				
Richardson		Dallas Aux.		2 Wells	1.10	59	100	54	336
Carrollton		Dallas Aux.		3 Wells		154	115	13	981
Dallas		5 Lakes	124.00	Wells	15.00	42	46	79	
Cockrell Hill		Dallas							
Farmers Branch		Dallas Aux.		Well	0.13e	212	465	16	1,640
Duncanville				3 Wells		86	169	11	930
WCID #2 (University Park & Highland Park)		Grapevine Lake	13.50						
WCID #6 (Balch Springs)			0.11	2 Wells	1.10	302	356	28	1,526
WCID #7 (Kleberg)				Well	0.90	278	175	20	1,410
Johnson									
Alvarado				2 Wells		38	195	16	864
Cleburne				9 Wells		43	88	8	580
Burleson				3 Wells	0.43	28	100	7	652
Keene				2 Wells		21	60	31	550
Ellis									
Italy				2 Wells	0.53	110	493		1,500
Midlothian				3 Wells	1.00	71	75	12	688
Ennis				3 Wells		147	72	365	843
Ferris				2 Wells		145	359	12	1,617
Waxahachie		Lake Waxahachie	3.00	4 Wells		9	20	110	144
NTMWD (Collin Co. - Plano, Farmersville, McKinney, Wylie Dallas Co. - Mesquite, Garland)	13.00	Lake Lavon	44.00			14	48	160	256
TOTAL	73.72		251.60		56.16				
Texas									
T-13									
Fannin									
Honey Grove	0.25			2 Wells	0.62	147	214	10	924
Ladonia				Well		1,633	189	303	3,710
Leonard				2 Wells	0.59e	61	190	8	840
Bonham	0.80			3 Wells	2.44e	118	195	5	1,050

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity Surface Water Source	 Yield (mgd)	 Ground Water Source	 Yield (mgd)	Water Supply Quality (mg/l) Cl⁻	 $SO_4^=$	 Hardness (as $CaCO_3$)	 DS
Texas									
T-13 (Continued)									
Lamar									
Paris	2.42	Pine Cr.	6.00			13	54	100	145
Delta									
Cooper	0.15	Cedar Cr. (Imp.)	0.36e			4	33	31	64
TOTAL	3.62		6.36		3.65				
Texas									
T-14									
Hopkins									
Sulphur Springs	0.86	White Oak Bayou & Lakes	5.00			11	31	55	81
Hunt									
Commerce	0.50			6 Wells		74	106	6	672
Wolfe City	0.15	Reservoir (Imp.)	0.28e			6	10	58	94
Greenville	2.50	Sabine R.	6.00e			14	28	100	150
Rockwall									
Royse City	0.09	NTMWD				10	39	70	145
Rockwall	0.05	NTMWD				53	215	17	956
Kaufman									
Terrell	1.07	Lake		7 Wells	2.00e	11	54	96	159
Forney		NTMWD				15	44	64	141
Kaufman	0.25	City & Kaufman Lake	0.35e			5	6	84	129
TOTAL	5.47		11.63		2.00				
Texas									
T-15									
Wood									
Winnsboro				Springs & Wells	1.28e	10	12	74	104
Mineola	0.40			3 Wells	1.98	13	21	29	180
Quitman	0.15			2 Wells	1.40e	15	101	102	270
Rains									
Emory	0.03			Well		80	288	390	630
Van Zandt									
Grand Saline	0.20	Lake (Imp.)	0.75e			225	11	14	690
Wills Point	0.30	Lake (Imp.)	1.00e			11	30	64	105
Canton	0.15			Well	0.30	22	26	97	200
Van	0.14	Lake (Imp.)	0.43e			57	65	90	263
TOTAL	1.37		2.18		4.96				
Texas									
T-16									
Red River									
Clarksville	0.40			2 Wells	2.00e	167	137	8	1,071
Bogata	0.06			2 Wells	0.25e	34	2	21	123
Franklin									
Mount Vernon	0.15	Mount Vernon Lake	0.36e			24	57	100	178
Titus									
Mount Pleasant	0.80	Lakes (Imp.)	1.00			36	23	80	146
Talco				Well		360	4	10	960
Morris									
Daingerfield	0.35			4 Wells	1.00e	13	34	59	131
Naples	1.20			3 Wells	0.16	47	6	8	395
Lone Star	0.10	Reservoir	1.29e	Wells		32	49	77	156
Camp									
Pittsburg	0.50			Wells	0.80	37	36	20	360
TOTAL	3.56		2.65		4.21				
Texas									
T-17									
Bowie									
DeKalb	0.13			5 Wells	0.34	46	49	58	211
Texarkana	2.30	Lake Texarkana Lake Bringle	18.00*						
New Boston	0.35			42 Wells		27	53	85	188
Hooks		Lake		Spring	0.72e	4	33	55	97
Wake Village	0.11			7 Wells	1.08e	191	1	61	450
Cass									
Atlanta	0.50			Wells	1.84	96	9	9	513
Linden	0.10			2 Wells		74	7	156	263
Hughes Springs				4 Wells	0.26	6	26	55	146
Queen City				4 Wells					
TOTAL	3.49		18.00		4.24				

* Texas and Arkansas

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quality				Water Supply Quality (mg/l)			
		Surface Water		Ground Water				Hardness	
		Source	Yield (mgd)	Source	Yield (mgd)	Cl^-	$SO_4^=$	(as $CaCO_3$)	DS
Texas									
T-18									
Marion									
Jefferson	0.38			2 Wells	0.65e	296	5	7	1,080
Upshur									
Gilmer	0.40			4 Wells	2.00	22	47	14	311
Gregg									
Longview	3.50	Big Sandy Cr.	55.00			27	13	44	102
Gladewater	0.73	Lake Gladewater	2.00e			31	16	37	99
Kilgore	1.50			5 Wells	4.80e	16	25	27	171
White Oak				Well		240	15	23	714
Harrison									
Marshall	2.50	Cypress Bayou	3.00			33	32	63	146
Waskom				Wells		161	79	73	899
TOTAL	9.01		60.00		7.45				
Texas									
T-19									
Rusk									
Henderson	1.00			7 Wells	4.00	16	16	9	300
Overton	0.30			3 Wells	0.43e	21	67	45	322
Panola									
Carthage	0.40			4 Wells	1.00e	33	11	30	267
TOTAL	1.70				5.43				
Missouri									
M-1									
Jasper									
Joplin (part)	6.40	Shoal Cr.	30.00			8	10	131	167
Carthage	1.10			6 Wells	2.80	37	57	107	246
Carterville	0.20	Webb City							
Webb City	1.00			3 Wells	0.74				
Sarcoxie	0.07			2 Wells	0.72				
Carl Junction	0.09			2 Wells	0.43				
Newton									
Granby	0.05			1 Well	0.35				
Neosho	0.30	Shoal Cr.	8.30	5 Wells	(Standby)				
Seneca	0.08			Wells	0.36				
Joplin (part)		Shoal Cr.							
TOTAL	9.29		38.30		5.40				
Missouri									
M-2									
Barton									
Lamar	0.25	Impoundment	66.00						
Dade									
Greenfield	0.09			2 Wells	0.26				
Lawrence									
Aurora	0.50			3 Wells	1.44				
Mount Vernon	0.30			3 Wells	1.40				
Marionville	0.12			1 Well	0.25				
Monett (part)				Wells					
Pierce City	0.08			Well	0.86				
Stone									
Barry									
Cassville	0.22			1 Well	0.51				
Monett (part)	0.50			6 Wells	2.90				
McDonald		Impoundment	0.58						
TOTAL	2.06		66.58		7.62				
Arkansas									
A-1									
Benton									
Bentonville	0.90			Springs	2.00	10	8	122	180
Siloam Springs	0.70	Lake Francis	10.00			9	12	118	168
Rogers	0.70	Lake Atlanta	3.00	Spring		14	8	127	175
Washington									
Springdale	1.00	Osage Cr.	7.00	Spring		9	12	147	161
Fayetteville	2.25	W. Fork White R.	3.50			6	11	67	91
Prairie Grove	0.05			Springs & Wells	0.34				
TOTAL	5.60		23.50		2.34				

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity: Surface Water Source	Surface Water Yield (mgd)	Ground Water Source	Ground Water Yield (mgd)	Water Supply Quality (mg/l): Cl^-	$SO_4^=$	Hardness (as $CaCO_3$)	DS
Arkansas									
A-2									
Carroll									
Berryville	0.22			Springs	0.33	9	33	113	161
Eureka Springs	0.12	Leatherwood Cr. (Imp.)	0.72e			4	13	99	169
Green Forest	0.11			Spring	0.36	8	8	233	249
Boone									
Harrison	0.85			Spring	2.00e	2	0	168	196
Madison									
Huntsville	0.06	War Eagle Cr.	0.29e			5	28	83	121
Newton									
Searcy									
Marshall	0.06			Well & Spring	0.12e	5	10	210	244
TOTAL	1.42		1.01		3.03				
Arkansas									
A-3									
Crawford									
Van Buren	0.50	Fort Smith Lee Cr.				15	42	76	143
Mulberry	0.10	Big Mulberry Cr.	0.26e			4	30	33	102
Franklin									
Ozark	0.20			5 Wells	0.50e	6	8	48	136
Charleston	0.06	Charleston Lake	0.36e			7	11	39	72
Johnson									
Coal Hill				Wells					
Clarksville	0.55			Wells	4.00	3	0	31	56
Pope									
Atkins	0.20			3 Wells	0.40e	8	7	151	225
Russellville	1.00	Illinois Bayou	1.52e			4	5	20	33
Logan									
Paris	0.36	Short Mountain Cr. (Imp.)	0.77e			7	23	40	56
Booneville	0.20	Barber, Fletcher, & City Lakes	0.50e			6	31	33	74
Scott									
Waldron	0.22	Square Rock Cr. (Imp.)	0.36e			9	17	41	88
Yell									
Dardanelle	0.28			3 Wells	0.50	73	23	130	345
Perry									
Conway									
Morrilton	0.50			4 Wells	1.75	25	20	136	219
Van Buren									
Cleburne									
Heber Spring	0.14	Little Red R.	0.28e			3	11	35	45
Faulkner									
Conway City	0.95	Cadron Cr. (Imp.)	2.00			3	11	21	50
TOTAL	5.18		6.00		7.23				
Arkansas									
A-4									
Sebastian									
Fort Smith	5.60	Lake Fort Smith	36.00e	Spring		3	8	31	20
Hartford	0.06			2 Wells	.06e	36	106	46	365
Huntington				Wells					
Greenwood	0.20	Vache Grasse Vineyard Cr.	0.36			16	42	41	160
TOTAL	5.86		36.36		.06				
Arkansas									
A-5									
Polk									
Mena	0.33	Lake Ward	0.60e			5	18	43	79
Montgomery									
Hot Spring									
Malvern	0.90	Ouachita	25.00			9	10	39	76
Clark									
Arkadelphia	0.70	Ouachita	48.00						
Gurdon	0.16			4 Wells	0.40e	150	40	10	567

e Estimated

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Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/l)			
		Surface Water		Ground Water				Hardness	
		Source	Yield (mgd)	Source	Yield (mgd)	Cl^-	$SO_4^=$	(as $CaCO_3$)	DS
Arkansas									
A-5 (Continued)									
Saline									
Benton	0.80	Saline R. & Brushy Cr.	6.00			4	3	36	100
Bauxite	0.25	Saline R.	5.00			10	20	77	110
Reynolds Metals		Hurricane Cr. Res.							
TOTAL	3.14		84.69		0.40				
Arkansas									
A-6									
Garland									
Hot Springs	2.89	Lakes Ricks, Sanderson, Bethel, and Dillon	15.00			7	6	36	41
TOTAL	2.89		15.00						
Arkansas									
A-7									
Pulaski									
Little Rock	17.40	Lake Winona	21.00						
		Lake Maumelle	83.00			4	0	28.6	47
Jacksonville	1.40			11 Wells	2.25	22	0	73	145
N. Little Rock		Little Rock							
Sherwood		Little Rock							
Commack		Little Rock							
Jefferson									
Pine Bluff	3.40			7 Wells	9.20	2.2	2	24	93
West End				Wells					
Pine Bluff Southwest				Wells					
TOTAL	22.20		100.00		11.45				
Arkansas									
A-8									
White									
Beebe	0.10			Well	0.40	81	7	51	329
Judsonia		Searcy							
Searcy	0.20	Little Red R.	2.00e			3	7	29	76
Bald Knob		Searcy				3	15	32	77
Lonoke									
Lonoke	0.20			2 Wells	0.36e	8	3	118	196
England	0.17			2 Wells	0.40e	34	20	248	376
Carlisle	0.12			2 Wells	0.20e	21	15	154	244
Cabot	0.08			2 Wells	0.47e	5	0	23	85
Arkansas									
DeWitt	0.25			2 Wells	0.75e	10	0	47	199
Stuttgart	0.75			4 Wells	2.00e	21	12	82	197
Monroe									
Clarendon	0.07			2 Wells	1.00e	67	0	81	394
Brinkley	0.40			2 Wells	1.50e	117	80	154	455
Prairie									
Des Arc	0.08			Well	0.50e	24	0	226	306
Hazen	0.06			2 Wells	0.18e	14	5	222	330
TOTAL	2.48		2.00		7.76				
Arkansas									
A-9									
Lafayette									
Stamps	0.23			2 Wells	1.50	7	5	39	130
Buckner	0.02			Well	0.14	11	0	83	124
Bradley	0.02			Well		137	0	28	658
Lewisville	0.15			2 Wells	0.50	11	3	65	133
Sevier									
Horatio	0.04			2 Wells	0.23e	0	1	58	50
DeQueen	0.30			6 Wells	1.30	8	1	95	225
Howard									
Nashville	0.35	Lake Nichols	0.32			15	10	50	118
Dierks	0.06	Lake Dierks				8	1	11	39
Pike									
Glenwood	0.10	Caddo R.	0.28e			8	8	53	81
Murfreesboro	0.06			Well	0.18e	1	2	10	34

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/l)			
		Surface Water		Ground Water					
		Source	Yield (mgd)	Source	Yield (mgd)	Cl^-	$SO_4^=$	Hardness (as $CaCO_3$)	DS
Arkansas									
A-9 (Continued)									
Little River									
New Rocky Comfort	0.10e			Wells					
Ashdown	0.15			5 Wells	0.50	32	12	180	319
Hempstead									
Hope	0.90			6 Wells	2.00	118	46	25	637
Miller									
Texarkana	3.80	Lake Texarkana	18.00*	23 Wells	1.20	16	24	61	158
TOTAL	6.28		18.60		7.55				
Arkansas									
A-10									
Nevada									
Prescott	0.74			4 Wells	0.50	126	68	111	663
Columbia									
Taylor	0.04			Well		8	1	30	89
Waldo	0.15			3 Wells	0.20e	23	2	37	396
McNeil	0.18			Well		8	11	144	250
Magnolia	0.80			4 Wells	0.50	9	11	16	234
Emerson	0.02			Well		3	0	20	151
TOTAL	1.85				1.20				
Arkansas									
A-11									
Ouachita									
Camden	1.00	Ouachita R.	130.00			7	12	40	76
Stephens	0.07			3 Wells	0.50e	5	6	33	130
Bearden	0.07			2 Wells	0.70e	11	7	48	155
Union									
El Dorado	2.53			10 Wells	9.00	31	0	4	278
Junction City	0.05			2 Wells		41	1	3	217
Huttig	0.11			Wells		216	0	6	689
Norphlet	0.04			Wells		34	0	4	313
Smackover	0.23			4 Wells		18	0	8	267
TOTAL	4.10		130.00		10.20				
Arkansas									
A-12									
Grant									
Sheridan	0.20			2 Wells	1.00	6	6	30	78
Dallas									
Fordyce	0.20			2 Wells		7	8	79	193
Cleveland									
Calhoun									
Hampton	0.04			3 Wells		11	10	6	231
Bradley									
Warren	0.58			3 Wells	2.00	6	3	12	218
TOTAL	1.02				3.00				
Arkansas									
A-13									
Lincoln									
Star City	0.16			Well & 13 Springs	0.30e	3	0	33	110
Gould	0.10			Well	0.35e	5	3	4	150
Desha									
Dumas	0.23			2 Wells		10	1	2	142
Arkansas City	0.05			2 Wells	0.65	15	3	3	215
McGehee	0.25			Wells		7	1	3	207
Drew									
Monticello	0.85			2 Wells		5	0	4	140
Ashley									
Hamburg	0.11			2 Wells	0.84e	70	12	209	409
Crossett	0.40			3 Wells	28.00	120	11	135	480

* Texas and Arkansas

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity				Water Supply Quality (mg/1)			
		Surface Water		Ground Water				Hardness	
		Source	Yield (mgd)	Source	Yield (mgd)	Cl^-	$SO_4^=$	(as $CaCO_3$)	DS
Arkansas									
A-13 (Continued)									
Chicot									
Eudora	0.20			2 Wells	0.60e	42	0	81	225
Lake Village	0.15			2 Wells		275	2	55	823
Dermott				2 Wells		15	1	4	225
TOTAL	2.50				30.74				
Louisiana									
L-1									
Caddo									
Shreveport	22.40	Cross Lake & 12 Mile Bayou	53.00			41	33	68	162
Vivian	0.35			3 Wells	1.00				
N. Shreveport	0.70	Shreveport							
Oil City	0.12	Caddo Lake							
Bossier									
Bossier City	3.00	Red R.							
Benton	0.01			3 Wells	0.40				
Plain Dealing	0.09			2 Wells					
Haughton	0.06			Well					
Webster									
Cotton Valley	0.08			2 Wells	0.36				
Spring Hill	0.32	Lake Erling	30.00	5 Wells	3.00				
Dayline	0.70			Well					
Minden	1.00			5 Wells	4.90				
Sibley				Wells					
Cullen	0.20			2 Wells					
TOTAL	29.03		83.00		9.66				
Louisiana									
L-2									
Claiborne									
Homer	0.50			6 Wells					
Haynesville	0.35			3 Wells	1.50				
Union									
Farmerville	0.30			2 Wells					
Bernice	0.10			2 Wells					
Lincoln									
Ruston	1.50			6 Wells		8	13	6	198
Grambling				Well					
Dubach	0.08			2 Wells					
Bienville									
Gibsland	0.07			3 Wells					
Arcadia	0.25			3 Wells					
Red River									
Coushatta	0.18			3 Wells					
De Soto									
Mansfield	0.65			6 Wells					
Logansport	0.25			4 Wells					
Jackson									
Jonesboro	0.50			3 Wells					
Hodge	0.33			Wells	1.50				
Winn									
Winnfield	0.75			4 Wells	1.76				
Caldwell									
Clarks	0.07			2 Wells	0.72				
Columbia	0.18			2 Wells					
Grant									
Colfax	0.13			2 Wells	0.13				
La Salle									
Jena	0.25			4 Wells	1.89				
Urania	0.05			2 Wells					
Olla	0.08			3 Wells					
TOTAL	6.57				7.50				
Louisiana									
L-3									
Ouachita									
Monroe	6.00	Bayou De Siard Ouachita R.	6.00 1,000.00			16	16	36	75
W. Monroe	0.80			4 Wells		19	0	2	299
Brownsville				2 Wells					
Splane Place				Wells					

e Estimated

Table II-1 (Continued)

Municipal Water Supply Data

State Subarea County Municipality	Present Average Demand (mgd)	Water Supply Quantity: Surface Water Source	Water Supply Quantity: Surface Water Yield (mgd)	Water Supply Quantity: Ground Water Source	Water Supply Quantity: Ground Water Yield (mgd)	Water Supply Quality (mg/l): Cl^-	Water Supply Quality (mg/l): $SO_4^=$	Water Supply Quality (mg/l): Hardness (as $CaCO_3$)	Water Supply Quality (mg/l): DS
Louisiana									
L-3 (Continued)									
Morehouse									
Bastrop	1.25	Bayou Bartholomew	30.00	Wells	12.00	186	2	6	697
TOTAL	8.05		1,036.00		12.00				
Louisiana									
L-4									
West Carroll									
Oak Grove	0.17			2 Wells	1.20				
East Carroll									
Lake Providence	0.35			3 Wells	2.88				
Richland									
Delhi	0.15	Bayou Mason							
Rayville	0.40			2 Wells					
Madison									
Tallulah	0.50			2 Wells					
Franklin									
Winnsboro	0.30			3 Wells	2.76				
Wisner	0.06			2 Wells					
Tensas									
Waterproof	0.10			Wells					
St. Joseph	0.18			Wells					
Newellton	0.17			2 Wells	0.76				
Catahoula									
Jonesboro	0.50			3 Wells					
Concordia									
Ferriday	0.30			3 Wells					
Vidalia	0.20			Wells	1.08				
Avoyelles									
Bunkie	0.40			3 Wells					
Cottonport	0.08			2 Wells					
Mansura	0.03			2 Wells					
Marksville	0.28			2 Wells					
Simmesport	0.15			2 Wells					
TOTAL	4.32				8.68				
Louisiana									
L-5									
Natchitoches									
Natchitoches	1.00			12 Wells	2.00				
Campti	0.10			Wells					
TOTAL	1.10				2.00				
Louisiana									
L-6									
Rapides									
Alexandria	5.00			21 Wells	8.16	28	17	213	476
Lecompte	0.20			2 Wells					
Glenmora				3 Wells	0.15				
Pineville	0.43			6 Wells	4.30				
Alexandria S.W.				Alexandria					
Anandale				Wells					
Samtown				Wells	1.00				
Cheneyville	0.15			2 Wells					
Boyce				2 Wells					
Pineville Junction		Rapides Parish W. D. No. 1							
Wardville				Wells					
TOTAL	5.78				13.96				

Quality

The quality of water needed for municipal purposes does not follow a particular set of standards since it serves so many masters. However, water used for domestic purposes is generally given primary consideration and quality recommendations for municipal supplies are usually governed by this use. As a result, high quality water is sometimes used where it is not needed. In other instances, water of much better quality than that recommended for domestic purposes is needed but is unavailable from public systems and, therefore, further treatment is necessary.

The most widely accepted municipal water quality standards are those published by the Public Health Service and adopted by the American Water Works Association for drinking water. [4] The Public Health Service Drinking Water Standards, first promulgated in 1894 as part of the Interstate Quarantine Regulations for prevention of interstate spread of disease, underwent the latest revision in 1962. First regulations, confined to bacteriological quality, were modified in 1925 to include limits for chemical constituents. Limitations in the latest standards (1962) include recommended permissible limits for chemicals that are generally nontoxic but have adverse qualities pertaining to color, odor, or taste. Listed are such constituents as copper, iron, chloride, sulfate, arsenic, nitrate, and dissolved solids. Supplies containing these chemical substances in excess of the recommended limits should not be used when other more suitable supplies are/or can be made available.

The suggested limit for the chloride ion concentration in the Public Health Service Standards is 250 milligrams per liter (mg/l). This standard is based on palatability, rather than health, and other agencies or countries have suggested levels from 10 to 500 mg/l. [5] Tests have disclosed that some individuals notice chloride salts (sodium chloride in particular) in water with concentrations of 100 mg/l; however,the taste becomes perceptable for the average individual when the salt is present in amounts greater than 200 mg/l.[5] Although adverse physiological effects may not occur except at high concentrations of chlorides (it is reported, up to 4,000 mg/l has no effect on the health of normal persons), lower levels may be injurious to some people suffering from diseases of the heart or kidney. [6]

Most of the chloride ion in the waters of the Arkansas-Red River basins is in the form of sodium chloride, consequently significant quantities of sodium are also present in these waters.* Sodium is reported harmful in excessive quantities to persons suffering from cardiac, renal, and circulatory diseases. It has been reported that drinking water of good quality may contain up to 115 mg/l of sodium, but a limit of 10 mg/l is usually recommended as desirable.[5]

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* When associated with the chloride ion (Cl^-) as common salt ($NaCl$), sodium (Na^+) is present in the ratio of .65 part sodium to 1 part chloride by weight.

Much of the waters delivered to consumers through public systems is used for other than domestic purposes, and adverse effects of high chloride concentrations on these uses are also of importance. Many portions of a subsequent discussion on industrial water quality requirements are also applicable to municipal supplies, since in many instances water from the municipal system satisfies much of the industrial demands. Some extent of myriad problems created by high chloride concentrations in municipal water supplies is illustrated by experiences in Dallas, Texas [7] in the mid 1950's when chlorides built up during an extended drought.

Dallas has a few standby deep wells, but water supply is normally obtained from surface reservoirs. At the beginning of the 1952 through 1956 drought, the city had only one major surface reservoir, Lake Dallas, on a tributary of the Trinity River. As the drought progressed, this source diminished rapidly through use and evaporation. Oilfield brines and concentration of dissolved solids caused by evapotranspiration raised sodium chloride levels (normally in the 60 to 120 mg/l range) 10-fold. Extreme shortages prompted installation of emergency pumping facilities on the Red River in early 1954. Through 11 miles of 48 inch pipeline, salty Red River water was transported over the drainage divide into the Lake Dallas watershed. Although diversion from the Red averaged less than 10 percent of the total municipal supply, daily analysis showed sodium chloride concentrations exceeding 1,400 mg/l (850 mg/l chlorides) before the drought broke in April 1957. Finished water hardness during this critical period was approximately 500 mg/l.

Although assessment of losses directly attributable to high chloride concentration was not attempted, a number of significant problems developed for Dallas residents using municipal water. Evaporative coolers, cooling towers, automobile radiators, and bimetallic plumbing fixtures corroded rapidly. It was not uncommon to repair items damaged by these corrosive tendencies twice in a single year. Lawns and shrubs irrigated with city water died or were severely stunted. Dietary adjustments for low salt intake patients were necessary. In response to popular demand, the city maintained free watering points at their wells to supply residents with drinking

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water. Dallas wells, in the Trinity Sands, are at a depth of 2,000 feet, contain sodium chloride (NaCl) of 200 mg/l and have temperatures varying from 110 to 125° F. Other residents purchased bottled water or soft drinks in preference to drinking tap water. Industries normally using Dallas city water supply employed various measures of expediency. Some transferred critical process operations to plants in other cities. Others installed expensive demineralizing equipment. A few hauled water in tank trucks from "fresh" city lakes or other sources.

These problems vividly illustrate why cities have not considered saline streams of the basins as a potential source of supply. Even the main stems are not used for municipal supply (though adequate quantities are available) except in two noteworthy instances (Table II-1). Denison, Texas, periodically uses the Red River to supplement limited yields of their basic sources of water supply. Bossier City, Louisiana, is constructing an off-channel storage reservoir with capacity sufficient to permit bypassing river water during low flow periods when quality is poorest.

Table II-1 presents data on municipal water supplies within the study area. Pertinent information is presented by State and subarea for each public water supply serving a population of 1,000 or more. It will be noted that 432 of the 658 individual supplies listed utilize ground water sources exclusively. The remainder obtain water from surface sources (170 systems) or a combination of ground and surface sources. Municipalities relying solely on ground water are for the most part smaller communities in the western and extreme eastern portions of the study area where surface supplies are unavailable, unreliable, of unsuitable quality, or too expensive for smaller communities to develop.

Also listed for each supply are quality parameters usually associated with establishing the suitability of a source of supply for municipal purposes. Although quality of water may vary markedly in some supplies during seasons of the year, particularly those obtained from surface sources, these data are intended to represent as closely as possible average conditions. Where results of several samples were available, concentrations presented are averages; where no data were available, results are presented of analyses conducted upon samples from the same surface stream or the same ground water aquifer near the municipality; where no data or estimates are available, nothing is entered.

It will be noted that none of the stream reaches potentially benefited by water quality improvement are listed in Table II-1 as a source of supply, except Denison and Bossier City. Although

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sufficient quantity of water could be developed in most of these streams, their generally poor quality has forced communities to seek other (ofttimes more distant and expensive to develop) sources to satisfy their increasing needs for water.

Industrial Water Use

Quantity

A large portion of the water currently used in the study area is directed toward satisfying the needs of industry. Some industrial demand is directly related to local population in the form of water used by countless small manufacturing and service industries closely associated with municipal growth. This portion of the total industrial demand is included in municipal water demands as discussed in the preceding section.

The largest portion of the industrial demand, however, is reflected in the needs of a few large water-using industries not directly related to population. The size and location of these industries is determined by many factors including: access to raw materials, access to market, power and labor cost, water supply, waste disposal, and economies of scale (plant size). These non-population oriented industries referred to in this report as principal water-using industries are:

Thermal Power Generation
Petroleum Refining
Chemical (Petrochemical) Production
Natural Gas Processing
Pulp and Paper Manufacture
Primary Metals Output
    (a) Iron and Steel
    (b) Aluminum
Food and Kindred Products Processing

About 2 percent of the 12 trillion gallons of water used by all the Nation's principal water-using industries (exclusive of thermal power generation) in 1960 was attributed to study area production. 8/ Since study area production by these industries is much greater than 2 percent of the national production (see economics section - Volume I), industrial water conservation measures are undoubtedly common practice in the study area. This fact is illustrated by data collected for the 1954 Census of Manufactures 9/ which shows actual industrial water intake to be 54 percent of the theoretical total requirement (if no recirculation had been practiced) in the Nation as a whole; whereas, in the Arkansas-White-Red River basins region, intake water was only 16 percent of the theoretical demand. (Greater detail on industrial water is presented in a later section of this chapter).

Quality

Many industrial processes cannot use, without further treatment, water considered acceptable for domestic purposes. For instance, water with over 75 mg/l chloride concentration is reportedly effective in promoting corrosion of certain metal parts used in paper manufacturing and damaging to the quality of the product; special chemical processes utilizing water as a conveying medium or as part of the product require water of near distilled quality; and carbon black industries using water for pelleting (packaging) require water with very low dissolved mineral content since residue remains in the product as an impurity. 10/

One of the most significant quality factors to large industrial water users is the concentration of dissolved solids, since it usually governs the permissible number of cycles and the frequency of blowdown in the recirculation of cooling water. If the quality of water is essentially constant and proper materials are used in construction of the cooling system, recirculation of waters with compositions approaching that of sea water have been found to be economical. On the other hand, some industrial processes are adversely effected by waters of less than 100 mg/l concentration, e.g., confectionary and rayon industries, 5/ particularly if specific ions obnoxious to the process are among the dissolved solids. Since a significant portion of the dissolved solids concentrations in waters of the Arkansas and Red Rivers are attributed to chloride salts, an examination of quality limitation of waters for industrial purposes due to chloride concentration is in order.

The presence of chlorides in industrial waters is a factor of importance to all of the principal water-using industries. The level of concentration, however, presents more problems for some than others. Chief objections to high chloride concentrations in industrial waters stems from the characteristic of chlorides to accelerate corrosion in piping and equipment. Chloride concentrations as low as 20 mg/l have been reported to be corrosive. 5/ Other objections involve impartation of tastes to products because of chlorides in process waters.

While the chloride concentrations at which water ceases to be useful are not available for all industries studied, Table II-2 lists the limits suggested for some industries by experts in the field.

Table II-2

Recommended Limits of Impurity to Protect Specific Uses

	Recommended Limit (mg/l)					
Impurity	Drinking Water	Irrigation	Paper	Food	Boiler	Steel
Dissolved Solids	500	350-700	200-500	850	50-3,000*	
Sulfate	250	200-480				
Chloride	250	70-178	75-200	20-250	210	175
Sum of Ca & Mg as $CaCO_3$	100		100-200	10-250	2-80*	50

*Exact figure is a function of pressure (i.e.; higher figure corresponds to low pressure).

Source: Public Health Service 11/, and California Water Pollution Control Board 12/

Irrigation Water Use

Quantity

Water utilized for the irrigation of crops presently is the largest single water use in the study area. In 1959, the study area acreage accounted for 13.4 percent of the estimated 33.2 million acres irrigated in the Nation. 13-14/ Area water requirements per acre range from 17 to 25 inches, depending on the location and type of crop irrigated. 15/ Of the total 1959 estimated irrigation water use of 8 million acre-feet, approximately 83 percent was supplied by ground water.

Quality

Water quality is an important factor in evaluating its usefulness for irrigation. There are, however, many aspects involved in evaluating the effects water of a given quality will have on plant growth. In general, good soil drainage may be a more important factor in crop growth than the quality of water. Even when excellent waters are used, poorly drained land may sometimes go out of production; while saline waters, on the other hand, may sometimes be used to irrigate tolerant crops when soil texture and structure permit sufficient leaching of the root zone.

Three criteria commonly used in establishing general suitability of waters to be used for irrigation of crops are:

1. Trace elements - Expressed as concentration of toxic ions.

2. Major cations and/or anions - Expressed as ionic concentration or the ratio of one ion to others.

3. Salinity - Expressed as total concentration of dissolved salts or the ability of water to conduct electric current (electrical conductivity expressed as micromhos per centimeter at 25° C).

Probably the most notorious example of a toxic trace element employed to classify irrigation water from a quality standpoint is boron. Although boron is essential for plant growth, the requirements are very small and the element may become toxic to many plants when concentrations above 1 or 2 mg/l are reached. 5/

Most of the major dissolved ionic constituents are essential nutrients for plant growth, but some are deleterious to sensitive plants or specific soils. The most common ionic measure of the suitability of a water for irrigation is the ratio of the sodium ion to the remaining cations. If the combining weight (equivalent weights per million - epm) of sodium exceeds that of calcium and magnesium, unfavorable soil conditions may develop. This is particularly true in clay soils where sodium ions tend to deflocculate the clay fraction and hinder water movement to the root zone. In addition to its effect on soil structure, sodium has a direct toxic effect on some plants as do other ions, such as chloride and sulfate. Excessive chlorides and sulfates often will cause tip burning of the leaves, and in some cases may be responsible for defoliation. Generally, for most crops, chlorides are considered more harmful than sulfates of equal concentrations, but recommended limits are approximately the same in terms of combining weights (<10 epm).

All ionized constituents contribute to the total osmotic effect. Osmotic pressures, directly proportional to concentration of salt solutions, may be so high that plant root experience difficulty in absorbing sufficient moisture for optimum growth. Since the ability of plants to extract adequate moisture differs, crops may be classified by salinity sensitivity. Table II-3 classifies some crops of importance in the study area.

Table II-3

Relative Tolerance of Crops to Salinity In Saturated Soil Extract*

High (ECX10^3 = 12 to 10)	Medium (ECX10^3 = 10 to 4)	Low (ECX10^3 = 4 to 3)
Vegetable Crops		
Beets	Most vegetables	Radishes
Asparagus		Celery
Spinach		Beans
Forage Crops		
Bermuda grass	Native grasses	Clovers
Alkali & salt grasses	Hay	
Field Crops		
Barley	Corn	Field beans
Sugar beets	Sorghum	
Cotton	Most small grains	

* Adapted from U.S. Department of Agriculture Handbook No. 60.

No exact limit can be set for the maximum permissible salt content of irrigation water, since such limitations depend greatly on the kind of salts in solution, soil type, subsoil drainage characteristics, crop tolerance, and farm management practices. In general, however, dissolved solids concentrations in soil solutions are from 3 to 10 times higher than those of the irrigation water. In most cases, the dissolved solids concentration for irrigation waters of acceptable quality, therefore, will range between 100 and 2,000 mg/l.[16] These concentrations are equivalent in most natural waters to electrical conductivity (EC) readings of 140 to 2,800 micromhos.

A general classification of irrigation waters assuming average soil types, cropping patterns, and farm management is given according to quality in Table II-4.

Table II-4

Classification*of Irrigation Water

Class**	Dissolved Solids (mg/l)	Dissolved Solids ECX10^6	Sodium (%)	Chlorides (mg/l)	Sulfates (mg/l)	Boron (mg/l)
1	<700	<1,000	<60	<178	<480	<0.5
2	700-2,100	1,000-3,000	60-75	178-355	480-960	0.5-1.0
3	>2,100	>3,000	>75	>355	>960	>1.0

* Developed from information contained in document of U.S. Department of Agriculture. 17/

** Class 1 - Excellent to good, or suitable for most plants under most conditions.

Class 2 - Good to injurious, harmful to some plants under conditions of soil, climate, and practice.

Class 3 - Injurious to unsatisfactory, unsuitable under most conditions.

Table II-5 classifies waters of the Arkansas and Red Rivers and their tributaries according to irrigation suitability. The sampling stations listed are those chosen by the Public Health Service to delineate and evaluate the natural salt source areas described in Volume I of this appendix. Stations located above sources of natural pollution are indicated by a #, the remainder are in stream reaches to be benefited by an improvement in water quality. All classifications are based on averages of analyses conducted upon weekly grab samples taken over two years of operation of the quality network.

These data show boron concentration is practically insignificant in waters of the Arkansas and Red Rivers. Under percent sodium concentration, Class 1 water quality is exceeded at 31 percent of the stations, most of which are in stream reaches to be benefited by the Arkansas-Red River project. Water of Class 1 sulfate quality exists at 90 percent of the sampling stations, indicating sulfate concentrations are almost insignificant in the Arkansas River basin from an irrigation suitability standpoint. Concentrations in the upper reaches of the Red River basin, however, are much more severe, primarily due to drainage over widespread gypsum outcrops.

Of the five quality measures listed in Table II-5, the two characteristics most consistently in the poor water range are chlorides and electrical conductance, or dissolved solids. Since specific conductance is significantly influenced by chlorides in these streams, the chloride ion appears to be the most significant single ionic quality hazard in these waters. With the present quality of water, irrigation is limited to particular stream reaches in the study area. For instance, the Red River is generally considered of unsuitable quality for irrigation except in the reach below Shreveport. 18/

streams, the chloride ion appears to be the most significant single ionic quality hazard in these waters. With the present quality of water, irrigation is limited to particular stream reaches in the study area. For instance, the Red River is generally considered of unsuitable quality for irrigation except in the reach below Shreveport. 18/

Table II-5

Irrigation Water Quality Classification (Irrigation Season*)

State	River Basin	Station Number	Station Description	Quality Criteria				
				E.C.** (or DS)	% Sodium	Chlorides	Sulfates	Boron
Kansas	Arkansas	2200	Arkansas River near Great Bend	2	1	1	2	1
		262	Rattlesnake Creek near Raymond	1	3	1	1	1
		266	Arkansas River below Hutchinson	2	1	3	1	1
		223	Arkansas River at Wichita	2	1	1	1	1
		227	Arkansas River at Arkansas City	2	1	2	1	1
		2290	Walnut River near Winfield	2	1	1	1	1
Oklahoma		7060	Salt Fork of Arkansas near Winchester	2	1	2	3	1
Kansas		2320	Medicine Lodge River near Kiowa	2	1	1	1	1
Oklahoma		235	Salt Fork of Arkansas near Jet	3	1	3	1	1
		236	Salt Fork of Arkansas near Tonkawa	3	1	3	1	1
		238	Arkansas River at Ralston	2	1	2	1	1
		2400	Cimarron River near Mocane	2	1	3	1	1
		862	Cimarron River near Buffalo	3	3	3	1	1
		248	Cimarron River near Waynoka	3	3	3	2	1
		251	Cimarron River near Guthrie	3	2	3	2	1
		253	Cimarron River near Perkins	3	3	3	1	1
		258	Cimarron River near Mannford	3	3	3	1	1
		259	Arkansas River at Tulsa	2	1	3	1	1
		2830	Verdigris River near Inola	1	1	1	1	1
		805	Arkansas River at Webbers Falls	2	1	2	1	1
New Mexico		3610	Canadian River at Logan	3	1	1	1	1
Texas		3620	Canadian River near Amarillo	2	1	1	1	1
		3630	Canadian River near Canadian	2	2	1	1	1
Oklahoma		3640	Canadian River at Bridgeport	2	2	2	1	1
		8380	Canadian River at Purcell	2	1	2	1	1
		3660	Little River near Tecumseh	1	1	1	1	1
		7630	Salt Creek of Little River near DeWright	3	2	3	1	1
		3670	Little River near Sasakwa	3	2	3	1	1
		3680	Canadian River at Calvin	2	1	2	1	1
		7620	N. Canadian River below Lake Overholser	1	1	1	1	1
		3870	N. Canadian River near Oklahoma City	2	1	3	1	1
		3880	N. Canadian River near Wetumka	2	1	3	1	1
		7650	Wewoka Creek near Wetumka	3	2	3	1	1
		3900	Deep Fork near Beggs	1	1	1	1	1
		7610	N. Canadian River near Eufaula	2	1	3	1	1
		3920	Canadian River near Whitefield	2	1	2	1	1
Arkansas		403	Arkansas River at Van Buren	2	1	1	1	1
Texas	Red	470	Prairie Dog Town Fork (Red) near Brice	3	2	3	3	1
		768	Prairie Dog Town Fork (Red) near Estelline	3	3	3	3	1
		750	Prairie Dog Town Fork (Red) near Quanah	3	3	3	3	1
		7030	Salt Fork near Wellington	2	1	2	3	1
Oklahoma		4810	Salt Fork near Mangum	2	1	1	3	1
		4830	North Fork River near Carter	2	1	2	2	1
		7540	Elm Fork at Salton Crossing	3	1	3	3	1
		753	Elm Fork near Carl	3	3	3	3	1
		490	North Fork River near Headrick	3	1	3	2	1
Texas		755	Pease River near Quanah	3	2	3	3	2
		759	Pease River near Vernon	3	1	3	3	2
		497	Red River near Burkburnett	3	2	3	2	1
Oklahoma		5000	Cache Creek near Walters	1	1	1	1	1
Texas		756	South Fork of the Wichita River near Benjamin	3	2	3	3	2
		757	North Fork of the Wichita River near Truscott	3	2	3	3	2
		758	Wichita River near Seymour	3	3	3	3	2
		752	Wichita River below Lake Kemp	3	1	3	2	2
		7510	Beaver Creek near Electra	2	1	3	1	1
		503	Wichita River at Wichita Falls	3	1	3	2	1
Oklahoma		7000	Beaver Creek near Waurika	2	1	1	1	1
Texas		7040	Little Wichita River near Henrietta	1	1	2	1	1
		507	Red River near Terral	3	1	3	2	1
		508	Red River near Gainesville	3	1	3	2	1
Oklahoma		5200	Washita River near Durwood	2	1	1	1	1
		522	Red River near Colbert	2	1	2	1	1
		5260	Clear Boggy Creek near Caney	1	1	1	1	1
Texas		527	Red River at Arthur City	2	1	2	1	1
Arkansas		529	Red River at Index	2	1	2	1	1

*Average of samples taken during irrigation season - June, July, August, and September

**E.C. - Electrical Conductivity.

***Stations which will not be benefited by reduction of natural brine emissions. Pollution caused chiefly by oilfield brines

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III. FUTURE WATER USE

Future municipal, industrial, and agricultural water demands are dependent on two variables: (1) The number of the water users at some future date (the year 2020) and (2) the unit water use factor of the user at the future time.

A determination of variable (1) involves economic and demographic projections. Variable (2) is somewhat dependent on economics but is probably best approximated by projecting historical trends in water use of the specific category.

Future water demands are obtained by multiplication of variable (1) by variable (2) in each water-using category. The following discussion describes the methodology used in this study's water use projections, presents supporting and supplemental data used in the projections, and outlines the water demands by the year 2020.

Municipal Water Demands

Methodology

Future municipal water demands for use in computing annual value of benefits are projected to the year 2020. These projections are developed by multiplying the projected population served by municipal water systems by a 2020 unit use factor in gallons per capita per day (gpcd).

Available water use data were collected for the period 1950-1960 from 44 municipalities throughout the study area. Cities not metered or having rationed water were excluded in order to form a more realistic projection base. Although longer term records are desirable, data previous to 1950 are not used because many cities had poor records, or none at all.

Municipal per capita requirement figures are calculated by subtracting any major industrial use from the total water use and dividing the adjusted use by the estimated population served. Table III-1 summarizes historic per capita water use data thus developed for the 44 cities.

To learn if variations noted in per capita use are associated with any of the usually investigated criteria, comparisons are attempted with municipal population-size group, population density, personal income, price of water, rainfall, climate factor, aridity factor, distance from a single isohyetal line and combinations of some of these variables. Of the factors investigated, only those

Table III-1

Historic Per Capita Water Use

Municipality	Year '50	'51	'52	'53	'54	'55	'56	'57	'58	'59	'60
Colo. Springs, Colo.	236	225	264	254	204	241	264	189	218	231	261
Pueblo, Colo.	352	337	334	337	306	262	260	249	260	250	236
Great Bend, Kans.	109	121	142	145	129	101	128	86	89	113	107
Hutchinson, Kans.	92	93	120	132	142	122	150	132	130	93	87
Wichita, Kans.	138	144	161	154	155	136	135	117	107	110	97
Coffeyville, Kans.	---	---	---	---	128	143	138	133	81	87	118
Parsons, Kans.	116	108	156	135	118	92	94	74	72	---	---
Pittsburg, Kans.	---	88	93	97	105	90	102	106	99	102	110
Altus, Okla.	---	---	---	---	---	149	162	138	145	145	146
Lawton, Okla.	---	---	---	---	---	---	146	134	140	137	139
Enid, Okla.	---	---	123	105	106	98	126	105	103	98	88
Duncan, Okla.	---	74	86	94	120	95	112	100	87	88	---
Ponca City, Okla.	---	102	114	104	115	110	124	105	105	102	100
Okla. City, Okla.	89	83	95	99	86	100	97	96	93	92	---
Norman, Okla.	83	87	89	95	101	88	102	93	95	87	---
Stillwater, Okla.	109	102	105	103	124	122	124	109	112	110	108
Tulsa, Okla.	108	105	102	105	104	110	118	102	106	111	---
Muskogee, Okla.	129	118	116	118	138	127	137	118	129	146	164
Okmulgee, Okla.	113	118	139	143	154	154	146	138	153	143	146
McAlester, Okla.	81	104	108	115	116	101	120	116	115	133	---
Amarillo, Tex.	---	---	---	---	---	---	171	---	169	---	144
Plainview, Tex.	165	167	188	224	226	169	211	162	166	181	---
Borger, Tex.	---	---	83	91	98	99	125	100	84	101	94
Pampa, Tex.	86	102	120	136	145	118	154	117	112	119	---
Wichita Falls, Tex.	129	166	177	142	139	134	156	119	120	139	128
Fort Worth, Tex.	95	112	127	122	131	126	140	129	125	126	---
Sherman, Tex.	80	86	97	89	92	98	109	91	98	95	---
Dallas, Tex.	121	127	139	127	147	140	161	141	140	145	140
Paris, Tex.	88	94	95	102	112	120	131	115	117	114	---
Longview, Tex.	---	---	---	---	---	---	124	96	95	104	---
Marshall, Tex.	104	105	107	118	129	124	129	123	120	128	---
Joplin, Mo.	124	132	139	139	147	142	154	162	162	165	167
Neosho, Mo.	---	---	---	---	---	139	132	91	123	121	115
Van Buren, Ark.	---	---	85	71	65	62	71	66	70	67	75
Fort Smith, Ark.	117	127	117	115	115	87	90	105	119	125	121
Texarkana, Ark.	72	81	83	82	82	69	98	81	80	68	---
Hot Springs, Ark.	---	---	---	---	---	88	92	92	96	101	115
Little Rock, Ark.	81	91	101	111	114	98	102	99	110	99	105
Pine Bluff, Ark.	---	---	---	---	---	87	82	79	84	95	93
Crossett, Ark.	55	68	66	71	69	69	70	67	68	73	---
Shreveport, La.	103	118	120	124	125	117	133	114	116	103	112
Alexandria, La.	80	92	113	106	113	96	106	102	131	111	109
Monroe, La.	130	138	129	128	135	127	136	124	127	113	---
Bastrop, La.	58	67	64	63	62	56	56	58	56	59	---

Source: Local Water Department personnel [1/]

pertaining to climate displayed a noticeable relationship. These factors all indicated that the water demand generally increased as the climate became dryer. Of the four factors pertaining to climate, rainfall data are more readily available; therefore, they are chosen for further investigation.

As noted in Table III-1, most cities had an abnormally high per capita demand in 1956. To determine the significance of this, historic precipitation data are assembled for 16 study area cities, including 13 of the 15 SMSA's (major municipal water demand centers). Data for these cities, representing all portions of the study area, are assembled in Table III-2.

Table III-2

Summary of Precipitation Records

Weather Station	Years of Record	Annual Precipitation (in.)				No. of Years Precipitation <1956
		Mean	Min.	(Year)	1956	
Pueblo, Colo.	57	11.90	5.78	(1934)	6.66	2
Raton, New Mex.	54	16.11	8.02	(1956)	8.02	0
Amarillo, Tex.	57	20.77	9.94	(1956)	9.94	0
Dodge City, Kans.	57	20.07	9.97	(1956)	9.97	0
Lubbock, Tex.	51	16.86	8.73	(1917)	10.83	3
Colo. Sps., Colo.	57	14.59	6.07	(1939)	10.93	6
Wichita, Kans.	57	30.12	12.73	(1956)	12.73	0
Ft. Worth, Tex.	57	31.51	17.91	(1921)	18.55	2
Wichita Falls, Tex.	38	26.34	16.36	(1952)	21.31	6
Dallas, Tex.	49	34.66	21.45	(1956)	21.45	0
Oklahoma City, Okla.	57	31.93	17.27	(1910)	22.56	6
Tulsa, Okla.	57	37.47	23.24	(1956)	23.24	0
Ft. Smith, Ark.	52	50.19	19.80	(1917)	30.68	6
Texarkana, Ark.	51	49.07	28.39	(1936)	31.44	2
Shreveport, La.	57	44.93	26.33	(1918)	34.01	6
Little Rock, Ark.	52	48.09	31.57	(1924)	52.34	37

Source: Weather Bureau 2/

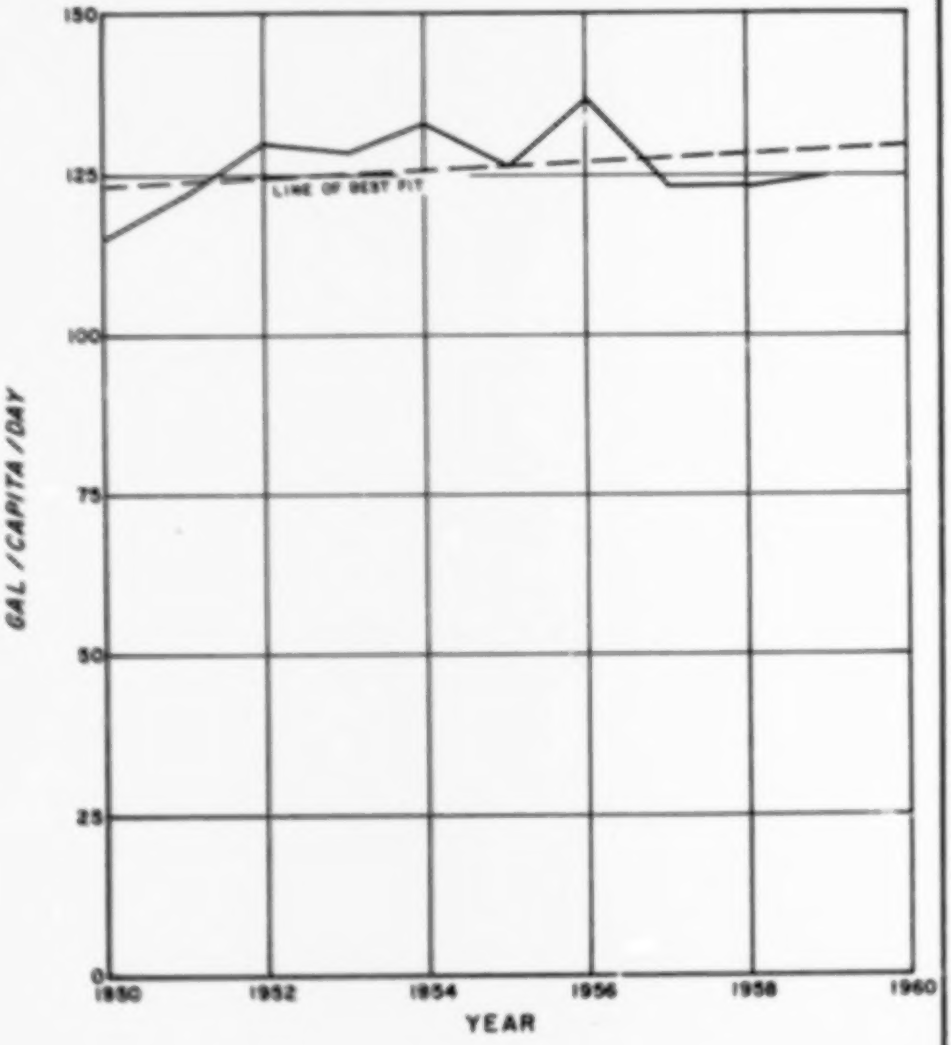
In eleven of the above listed stations, the lowest annual precipitation fell in 1956 since 1936 and at six of the stations it was the year of least annual precipitation of record. Exceptions to the "generally dry" classification of 1956 occurred in some portions of the eastern study area. Little Rock, for instance, had slightly greater than mean precipitation during the year. These areas of exception are few, however, and apparently of limited areal extent since the lowest annual runoff ever recorded on the Arkansas River at Little Rock, and the Red River at Shreveport, occurred during the calendar year 1956.3/

With regard to the series of dry years in the mid-1950's, the Weather Bureau states that 1952-1956 drought has not generally been matched in severity since the latter part of the 19th century, and has not been exceeded in most study area States since the beginning of reliable records. Return period of the 1952-1956 drought are of the order of 40 years in Texas, Colorado, and New Mexico; and roughly 140 years in Oklahoma and Kansas. 4/

On the above basis, 1956 is selected as a base for designing "dry year" demands because it was generally dry throughout most of the study area and reliable water use data representing recent conditions are readily available. Table III-3 demonstrates the relationship between 1956 gpcd and precipitation at various municipalities throughout the study area.

With increasing use of such appliances as automatic clothes washers, dish washers, and garbage disposals, as well as the advent of the backyard swimming pool, and well-watered yards, an increase in domestic water use has been noted with the passage of time. To determine if such an increase prevailed in the study area, historic per capita use data in all communities for which ten years of record is available are averaged. Weighted per capita demands for the years 1950 through 1959 indicated an average annual increase of 0.62 gpcd per year existed in these 27 cities. (See Figure III-1.) Assuming the same rate of increase would pertain for the next 60 years, an increase of 37 gpcd could be expected by the year 2020.

It is assumed that in the year 2020, cities in the study area will have similar water use characteristics. Therefore, to obtain a per capita base for projection, present "dry year" conditions are normalized. This is done by averaging the gpcd's of cities with similar traits in the same precipitation belt. The previously calculated 37 gpcd increase is then added to the present normalized demand to obtain the gpcd figures for 2020. Some example municipalities



ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

MUNICIPAL WATER USE TRENDS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE III - 1

Table III-3

1956 Precipitation vs. GPCD

Municipality	Precipitation (inches) a/	GPCD b/
Plainview, Texas	9	211
Amarillo, Texas	10	171
Pampa, Texas	11	154
Borger, Texas	12	125
Enid, Oklahoma	13	126
Wichita, Kansas	13	135
Great Bend, Kansas	14	128
Hutchinson, Kansas	14	150
Colo. Springs, Colo.	14	264
Stillwater, Okla.	14	124
Ponca City, Okla.	15	124
Altus, Oklahoma	18	162
Fort Worth, Texas	19	140
Okmulgee, Oklahoma	19	146
Wichita Falls, Texas	21	156
Norman, Oklahoma	21	102
Lawton, Oklahoma	21	146
Oklahoma City, Okla.	23	97
Tulsa, Oklahoma	23	118
Sherman, Texas	23	109
Coffeyville, Kansas	24	138
Parsons, Kansas	24	94
Muskogee, Oklahoma	27	137
McAlester, Oklahoma	27	120
Paris, Texas	29	131
Marshall, Texas	30	129
Neosho, Missouri	30	132
Van Buren, Arkansas	31	71
Fort Smith, Arkansas	31	90
Texarkana, Tex. & Ark.	31	98
Joplin, Missouri	32	154
Longview, Texas	33	124
Shreveport, Louisiana	34	133
Alexandria, Louisiana	46	106
Bastrop, Louisiana	47	69
Monroe, Louisiana	48	136
Pine Bluff, Arkansas	48	82
Little Rock, Arkansas	52	102
Hot Springs, Arkansas	55	92

Source: a/ Weather Bureau 2/
b/ Region VII Public Health Service Personnel.

are presented in Table III-4. The approximate projected rates rounded to the nearest 5 gpcd are multiplied by the projected population served by municipal water systems to obtain the 2020 municipal water demand for each subarea.

Table III-4

Municipal Water Demand Projections

Municipality	Dry Year Expected Precipitation (inches)	Dry Year Normalized Demand Present (gpcd)	Dry Year Normalized Demand 2020 (gpcd)
Amarillo, Texas	10	161	200
Wichita, Kansas	13	147	185
Altus, Oklahoma	18	147	185
Tulsa, Oklahoma	23	137	175
Paris, Texas	29	130	165
Texarkana, Texas	31	121	155
Fayetteville, Ark.	39	112	145
Ruston, Louisiana	43	100	135
Little Rock, Ark.	50	88	125

Projected Water Demands

Subarea municipal water requirements projected to the year 2020 are computed by multiplying a unit use factor (gpcd) by the expected projected population served by municipal water systems.

Gallons per capita per day for the period 1950-1960 were calculated from data collected at 44 cities in the study area.(Table III-1). In reviewing these data, a general increase in gpcd was also apparent for the year 1956. Gpcd figures were compared with several parameters to determine whether any single factor or combination of factors were significant in causing the varying rate of use. This examination indicated that the rate of water use generally increased as climate approached aridity. Rainfall data, being a readily available climatic indicator, was chosen as the governing criterion for projection of 2020 use rates. Since municipalities do not all have the same water use characteristics, present "dry year" (1956) rates were normalized to form a base for projecting future dry year unit demands.

By plotting weighted (by population served) gpcd figures from 1950 through 1959, an average increase of 0.62 gpcd/yr. was shown for the study area. Assuming that this average rate will continue, an increase of 37 gpcd can be expected by the year 2020. Thirty-five to forty gpcd was added to the present normalized dry year rates to obtain future design year demand rates varying from 115 to 205 gpcd as presented in Table III-5 by precipitation belts. The appropriate projected rate multiplied by the expected 2020 population served by municipal water systems provides the subarea municipal water demands presented in Table III-6 at the end of this section. Also included in Table III-6 are the projected water requirements for industrial use. A discussion of the industrial projection methodology and supplemental data follow Table III-6 in the industrial section.

Table III-5

2020 Municipal Dry Year Unit Water Demands

Annual Precipitation Range (inches)	Unit Demand Range (gpcd)
< 10	205-195
10-15	195-185
15-20	185-175
20-25	175-165
25-30	165-155
30-35	155-150
35-40	150-145
40-45	145-135
45-50	135-125
> 50	125-115

Industrial Water Demands

Methodology

Industrial water use is that which is a function of the size and type of industrial plant and the conservation measures practiced by the plant. It is not directly related to the population of the area in which the industry is located, but is more nearly expressed as the number of gallons per unit of product than any other measure.

Table III-6

2020 Municipal and Industrial Subarea Water Requirements
(mgd)

Map Designation	Area	Municipal	Industrial								Total Projected Requirements	
			Oil Refining	Natural Gas	Petrochemical	Iron & Steel	Aluminum	Pulp & Paper	Food & Kindred	Thermoelectric	M & I High Quality	Cooling Low Quality
Colorado												
C-1	Pueblo-Colorado Springs	253				*76			2	59	331	59
C-2	Lamar	7								2	7	2
C-3	Canon City	8								2	8	2
C-4	Trinidad	7							**4	2	11	2
Subtotal		275				76			6	65	357	65
New Mexico												
NM-1	Raton	8								2	8	2
NM-2	Clovis	14								4	14	4
Subtotal		22								6	22	6
Kansas												
K-1	Garden City	34	4	31						8	47	30
K-2	Larned	4								1	4	1
K-3	Dodge City	10								2	10	2
K-4	Medicine Lodge	4								1	4	1
K-5	Pratt	7								2	7	2
K-6	Great Bend	14								3	14	3
K-7	Newton	15	13						1	4	21	12
K-8	Wichita	306	64	1	46				2	78	340	157
K-9	Wellington	8								3	8	3
K-10	Eureka	5								2	5	2
K-11	Emporia	24	44						2	7	33	44
K-12	Coffeyville	8	34						1	2	15	30
K-13	Pittsburg	6							1	2	7	2
Subtotal		443	159	32	46				7	115	515	289
Oklahoma												
O-1	Guymon	6		2						2	8	2
O-2a	Woodward	6								2	6	2
O-2b	Clinton	15		1						5	16	5
O-3	Alva	5								2	5	2
O-4	Enid	17	13						1	6	23	12
O-5	Ponca City	14	43	2	22				1	4	39	47
O-6	Tulsa	272	116		48				2	70	301	207
O-7	Stillwater	22	21							7	29	21
O-8	Oklahoma City	315		1					2	80	318	80
O-9	Duncan	26	33	2						8	39	30
O-10	Lawton	47								13	47	13
O-11	Altus	8								2	8	2
O-12	Frederick	6	3							2	7	4
O-13	Ardmore	11	11							3	15	10
O-14	Shawnee	26		1						9	27	9
O-15	Muskogee	20	27						1	6	25	29
O-16	Claremore	16						3		5	19	5
O-17	Miami	8								4	8	4
O-18	McAlester	8								2	8	2
O-19a	Poteau	7						25		3	32	3
O-19b	Hugo	8						49		3	57	3
O-20	Durant	12								4	12	4
Subtotal		875	267	9	70			77	7	240	1,049	496

* Includes water used by the steel industry for cooling (must be of better quality than average cooling water).

** Includes 3 mgd seasonal demand during beet sugar campaign.

Table III-6 (Continued)

2020 Municipal and Industrial Subarea Water Requirements
(mgd)

Map Designation	Area	Municipal	Industrial: Oil Refining	Industrial: Natural Gas	Industrial: Petro-chemical	Industrial: Iron & Steel	Industrial: Aluminum	Industrial: Pulp & Paper	Industrial: Food & Kindred	Industrial: Thermo-electric	Total Projected Requirements: M & I High Quality	Total Projected Requirements: Cooling Low Quality
Texas												
T-1	Dalhart	28	106	59					1	7	91	110
T-2	Amarillo	209	79	1	25					46	248	112
T-3	Pampa-Borger	37	30	4	25					9	39	46
T-4a	Canadian	1								1	1	1
T-4b	Childress	5								2	5	2
T-5	Hereford	25								7	25	7
T-6	Plainview	18							1	5	19	5
T-7	Vernon	10								3	10	3
T-8	Wichita Falls	81	9		14					19	90	33
T-9	Graham	9								3	9	3
T-10	Weatherford	12		3						4	13	6
T-11	Sherman	35	2	1					1	10	37	12
T-12	Dallas-Fort Worth	1,114	16					1	10	283	1,129	295
T-13	Paris	22							19	7	41	7
T-14	Greenville	24							1	7	25	7
T-15	Mineola	5								2	5	2
T-16	Mt. Pleasant	9	27			33				3	46	26
T-17	Texarkana	17						45		6	62	6
T-18	Marshall	34	15	2	111			28		11	83	118
T-19	Henderson	8		4						3	9	6
Subtotal		1,703	284	74	175	33		74	33	438	2,007	807
Missouri												
M-1	Joplin	16							1	6	17	6
M-2	Aurora	9							3	4	12	4
Subtotal		25							4	10	29	10
Arkansas												
A-1	Fayetteville	15							6	6	21	6
A-2	Harrison	4								3	4	3
A-3	Van Buren	22						70	5	10	97	10
A-4	Fort Smith	24							2	7	26	7
A-5	Benton	12					12			5	24	5
A-6	Hot Springs	10								4	10	4
A-7	Little Rock	96						33	3	37	132	37
A-8	Stuttgart	11							1	6	12	6
A-9	Texarkana	12								5	12	5
A-10	Magnolia	6		2	25					2	9	26
A-11	El Dorado	19	142		94			43		7	92	213
A-12	Warren	5								3	5	3
A-13	Crossett	12						23		6	35	6
Subtotal		248	142	2	119		12	169	17	101	479	331
Louisiana												
L-1	Shreveport	146	32	3	143			52	2	46	223	201
L-2	Ruston	27		1				20		12	48	12
L-3	Monroe	47		1	150			80		19	128	149
L-4	Tallulah	16		1					2	10	19	10
L-5	Natchitoches	6								3	6	3
L-6	Alexandria	35						18	1	14	54	14
Subtotal		277	32	6	293			150	5	104	478	389
Grand Total		3,870	884	123	703	109	12	470	79	1,079	4,936	2,393

The necessity for making a separate projection of industrial water will depend on its magnitude in relation to the total water demand. This may vary from a negligible quantity in a large urban area with diversified industry to several times the municipal component when there is a predominance of the so-called "wet" industries. The "wet" or principal water-using industries include those described in Senate Select Committee Print No. 8 [5] and thermal electric power plants. Of these, the following industries are expected to exert significant demands in the Arkansas-Red River basins during the next 60 years.

1. Thermal Power Generation
2. Petroleum Refining
3. Petrochemical Production
4. Natural Gas Processing
5. Pulp and Paper Manufacture
6. Primary Metals (iron, steel, aluminum) Output
7. Food and Kindred Products Production

The methodologies employed in projecting water demands for each follow and a summary is presented in a table at the conclusion of this chapter.

Thermal Power Generation

Thermal power generation is the largest water user in industry. In 1959, approximately 70 percent of the total industrial water was used within this industry. [5-7] This, however, is the total water requirement and not consumptive use as developed in this report. Table III-7 provides comparative data on water requirements for thermo-power generation in the Nation.

Consumptive use of water for thermal power can be defined as that portion of the total water required which is lost to evaporation. If the water is taken from a lake or stream, it is returned to its source with little, if any, change in chemical quality.

A study conducted by the Bureau of Business Research of the University of Texas on circulating water requirements indicates a range from 40 gallons per net kilowatt-hour generated in newer plants to around 100 gallons per kilowatt-hour for older plants. The report also points out that consumptive use of circulating water at plants using cooling tower or spray ponds ranges from 0.6 gallon per kilowatt-hour for newly installed plants to 1.2 gallons per kilowatt-hour for the older installations.

TABLE III-7

WATER REQUIREMENTS OF ELECTRIC UTILITY STEAM-ELECTRIC GENERATING PLANTS - 1959
SUPPLY, RECIRCULATION, AND LOSSES

GEOGRAPHIC AREA	TOTAL GENERATION KWH (Thousands)	% COVERAGE	MILLIONS OF GALLONS							TOTAL USE IN GALLONS PER KWH
			WATER SUPPLY			RECIRCULATION	TOTAL USE	LOSSES	DISCHARGED	
			FRESH	BRACKISH	TOTAL					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
NEW ENGLAND	21,683,278	95-58	201,135	1,190,223	1,391,358	49,198	1,440,556	1,790	1,389,568	66.44
Maine	838,979	83.83	52	35,514	35,566	867	36,433	23	35,543	43.42
New Hampshire	1,168,653	99.31	43	50,903	50,946	1,244	52,190	29	50,917	44.65
Vermont	36,390	97.08	6,146		6,146	55	6,201	106	6,040	170.40
Massachusetts	11,004,423	95.74	83,621	464,290	547,911	33,868	581,779	1,011	546,900	52.87
Rhode Island	1,464,547	92.30	332	137,271	137,603	5,087	142,690		137,603	97.43
Connecticut	7,170,286	97.03	110,941	502,245	613,186	8,077	621,263	621	612,565	86.65
MIDDLE ATLANTIC	93,713,247	99.63	3,400,758	2,762,760	6,163,518	164,886	6,328,404	10,990	6,152,528	67.53
New York	37,744,586	99.81	980,050	1,888,585	2,868,635	36,443	2,905,078	5,637	2,862,998	76.97
New Jersey	17,202,794	99.64	226,095	874,175	1,100,270	38,574	1,138,844	3,264	1,097,006	66.20
Pennsylvania	38,765,867	99.45	2,194,613		2,194,613	89,869	2,284,482	2,089	2,192,524	58.93
EAST NORTH CENTRAL	151,182,612	98.27	8,679,022		8,679,022	309,619	8,988,641	7,361	8,671,661	59.46
Ohio	46,901,294	98.07	2,632,582		2,632,582	146,483	2,779,065	3,147	2,629,435	59.25
Indiana	28,601,045	98.56	1,525,302		1,525,302	37,860	1,563,162	1,509	1,523,793	54.65
Illinois	40,751,738	98.83	2,475,698		2,475,698	87,437	2,563,135	1,562	2,474,136	62.90
Michigan	23,970,020	98.10	1,348,575		1,348,575	26,957	1,375,532	869	1,347,706	57.38
Wisconsin	10,958,515	96.69	696,865		696,865	10,882	707,747	274	698,591	64.58
WEST NORTH CENTRAL	28,837,424	85.50	1,445,721		1,445,721	567,234	2,012,955	11,915	1,433,796	69.80
Minnesota	6,355,789	84.81	376,451		376,451	14,725	391,176	153	376,298	61.55
Iowa	5,562,141	87.22	340,905		340,905	112,195	453,100	4,782	336,123	81.46
Missouri	7,650,924	86.04	413,869		413,869	69,378	483,247	1,396	412,473	63.16
North Dakota	122,722	12.89	355		355	7,302	7,657	178	177	62.39
South Dakota	328,344	67.44	335		335	24,574	24,909	253	82	75.86
Nebraska	2,381,347	83.55	156,943		156,943	6,947	163,890	155	156,788	68.82
Kansas	6,436,157	92.25	156,863		156,863	332,113	488,976	4,998	151,855	75.97
SOUTH ATLANTIC	84,179,776	98.58	3,045,772	2,147,043	5,192,815	223,061	5,415,876	4,735	5,188,080	64.34
Delaware	2,220,858	98.84	647	162,548	163,195	3,206	166,401	550	162,645	74.92
Maryland	6,497,955	97.15	65,954	303,293	369,247	6,208	375,455	218	369,029	57.78
District of Col.	1,269,281	100.00	160,615		160,615	1,530	162,145	25	160,590	127.75
Virginia	16,371,216	98.92	572,315	330,050	902,365	134,719	1,037,084	2,154	900,211	63.35
West Virginia	13,533,099	100.00	710,598		710,598	11,276	721,874	195	710,403	53.34
North Carolina	14,010,865	98.14	567,875	46,785	614,660	23,555	638,215	572	614,088	45.55
South Carolina	6,017,647	98.52	255,131	43,332	298,463	7,966	306,429	537	297,926	50.92
Georgia	9,178,784	99.31	516,481	65,303	581,784	9,825	591,609	41	581,743	64.45
Florida	15,080,071	97.26	196,156	1,195,732	1,391,888	24,776	1,416,664	443	1,391,445	93.94
EAST SOUTH CENTRAL	65,825,630	99.22	2,906,699	95,762	3,002,461	308,142	3,310,603	5,354	2,997,107	50.29
Kentucky	16,619,508	98.77	798,774		798,774	59,886	858,660	728	798,046	51.67
Tennessee	29,531,146	99.94	1,290,417		1,290,417	29,611	1,320,028	269	1,290,148	44.70
Alabama	16,976,524	99.21	777,446	61,209	838,675	49,848	888,523	93	838,582	52.34
Mississippi	2,698,454	94.50	40,042	34,553	74,595	168,797	243,392	4,264	70,331	90.19
WEST SOUTH CENTRAL	54,742,920	97.62	790,102	529,546	1,319,648	2,263,297	3,582,945	31,191	1,288,457	65.45
Arkansas	4,379,764	99.88	77,685		77,685	180,137	257,822	2,121	75,564	58.87
Louisiana	9,959,455	96.75	235,061	90,256	325,317	192,007	517,324	6,475	318,842	51.94
Oklahoma	6,645,800	95.98	43,895	430	44,325	340,903	385,228	4,334	39,991	57.97
Texas	33,757,811	97.91	433,461	438,860	872,321	1,550,250	2,422,571	18,261	854,060	71.76
MOUNTAIN	14,117,085	93.38	102,628		102,628	789,917	892,545	9,392	83,238	63.22
Montana	156,281	72.87	6,655		6,655	178	6,833	3	6,652	43.72
Idaho										
Wyoming	651,843	89.59	19,369		19,369	5,439	24,808	164	19,205	38.05
Colorado	3,316,315	86.51	27,583		27,583	190,949	218,532	2,182	25,401	65.90
New Mexico	2,586,018	92.28	3,282		3,282	196,482	199,744	2,273	989	77.84
Arizona	4,560,924	99.49	26,011		26,011	228,426	254,437	3,105	22,906	55.78
Utah	2,382,288	95.50	19,110		19,110	146,201	165,311	1,344	17,766	80.98
Nevada	503,436	100.00	638		638	22,242	22,880	321	317	45.45
PACIFIC	40,401,826	99.54	8,107	1,623,010	1,631,117	627,274	2,258,391	6,405	1,624,722	55.90
Washington										
Oregon										
California	40,401,826	99.63	8,107	1,623,010	1,631,117	627,274	2,258,391	6,405	1,624,722	55.90
UNITED STATES TOTAL	554,683,798	97.68	20,579,944	8,348,344	28,928,288	5,302,628	34,230,916	89,133	28,839,155	81.71

The projected consumptive use of water for thermal power generation in the study area is best established by relating the projected unit energy requirement to unit consumptive water use per unit of energy of energy produced. As discussed in Chapter I, energy requirements are projected on the basis of a per capita kilowatt-hour consumption of electrical energy.

Increased efficiency in power plants indicates a decrease in the needed gallons per kilowatt-hour. As stated previously and as reported by the Senate Select Committee, a drop from 1.2 gallons per kilowatt-hour to 0.6 gallon per kilowatt-hour should be noted in the newer installations. 7/ In the year 2020 it was assumed that the average generating plant would require approximately the consumptive use found in the better plants of today. Therefore, a figure of 0.7 gallon per kilowatt-hour was selected for this study area for the year 2020.

The projected populations for each subarea for 2020 were then used as a basis for the consumptive water use. The population figures for each subarea multiplied by the established projected kilowatt-hour per capita per day figure times the 0.7 gallon per kilowatt-hour selection gives the estimated consumptive water use.

Petroleum Refining

In projecting water demands for the petroleum refining industry, the following methodology is employed.

1. The projected petroleum refinery output in barrels of petroleum per day is multiplied by a unit water demand (1,722 gal. of water per barrel of petroleum refined) 8/ to obtain a total once through (no recirculation) water demand.

2. The total demand was divided into a cooling water demand which ranges between 95 and 99 percent 9/ of the total once through demand and a miscellaneous water use demand which includes process water and sanitary water and ranges between 1 and 5 percent 9/ of the total once through demand. (For this report, an average of 97 percent and 3 percent is used for cooling and miscellaneous demand, respectively.)

3. The expected areas of refinery expansion were then investigated more thoroughly as to availability of water to determine the percent of the once through cooling water requirement which could be supplied by the area if recirculation were practiced. The percentage thus established is used to determine the total cooling water demand for each area.

4. The total projected water demand was then determined by adding the cooling water demand with the miscellaneous water demand.

The following assumptions are used:

1. Since large dependable supplies of water that might be used for cooling are scarce in the western half of the Arkansas-Red River basins (west of Wichita Falls, Texas, and Wichita, Kansas), it is assumed that large water-using industries in this area will tend to obtain maximum use of available water. Generally, this would mean maximum recirculation of cooling water. The demand under these conditions would be about 5 percent[8,10] of the once through cooling water requirement.

2. Principal water-using industries in the eastern half of the basins will tend to approach the national average in recirculation. The average demand at present is about 27 percent of the once through cooling water requirement.[8] With increased utilization of air cooling and improved heat transfer methods, the unit water demand is expected to decrease.[5,11] The average for 2020 is estimated at about 20 percent of the once through cooling requirement.

Projected water demands to the year 2020 for the petroleum refining industry in the study area are given in Table III-8. Projected oil production figures were then taken from Table I-5 in Chapter I - Economics Projections.

Petrochemical Production

The following methodology is utilized in projecting petrochemical production water demands.

1. Demands prorated among areas in the study area in tons of production were tied to unit water demand[12] to obtain a total cooling water demand based on once through use.

Table III-8

Projected Water Demands for Study Area Petroleum Refining Industry

Map Designation	General Area of Expansion	Proj. 2020 Prod. Bbl./Day	Cooling Water: Once Thru Demand Per Bbl. of Prod. (gal.)	Cooling Water: Demand W/ Recirculation (% of once thru)	Cooling Water: Proj. Demand (mgd)	Water For Other Purposes (mgd)	Total Water Demand (mgd)
Kansas							
K-7	McPherson	92,500	1,670	5	8	5	13
K-8	Wichita-El Dorado	465,000	1,670	5	40	19	64
K-11	Neodesha	143,000	1,670	15	37	7	44
K-12	Coffeyville	111,000	1,670	15	28	6	34
Oklahoma							
O-4	Enid	95,300	1,670	5	8	5	13
O-5	Ponca City	320,600	1,670	5	27	16	43
O-6	Tulsa	375,000	1,670	15	97	19	116
O-7	Cushing	121,000	1,670	10	16	5	21
O-9	Duncan-Wynnewood	242,000	1,670	5	21	12	33
O-12	Crandfield	22,100	1,670	5	2	1	3
O-13	Ardmore	76,700	1,670	5	7	4	11
O-15	Okmulgee	86,000	1,670	15	22	5	27
Texas							
T-1	Sunray	76,800	1,670	5	7	4	11
T-2	Amarillo	57,400	1,670	5	5	3	8
T-3	Phillips	216,000	1,670	5	19	11	30
T-8	Wichita Falls	68,900	1,670	5	6	3	9
T-11	Gainesville	6,390	1,670	15	1	1	2
T-12	Dallas-Ft. Worth	51,200	1,670	15	13	3	16
T-16	Mt. Pleasant	86,000	1,670	15	22	5	27
T-18	Longview	47,600	1,670	15	13	2	15
Arkansas							
A-11	El Dorado	360,000	1,670	20	123	19	142
Louisiana							
L-1	Shreveport	79,600	1,670	20	28	4	32
		3,200,090					

Source: Senate Select Committee 8/, and Bureau of the Census 9/

2. The expected areas of petrochemical manufacturing expansion were then investigated more thoroughly as to availability of water to determine the percent of the once through cooling water requirement which could be supplied by the area if recirculation were practiced. The percentage thus established is used to determine the total cooling water demand for each area.

3. The total projected water demand was determined by adding the cooling water demand with a constant demand for miscellaneous needs.

The following assumption is used:

The future once through cooling water requirement per unit of production will approximate the present requirements listed in the Department of Commerce report, "Location Factors in the Petrochemical Industry." [12] As determined from this report, the average cooling water demand for the types of petrochemicals expected to be produced in the basins is 42 gallons per pound (84,000 gal./ton).

Projected petrochemical production water requirements for the study area are given in Table III-9.

Natural Gas Processing

A total water demand for the gas processing industry in the Arkansas-Red River basins was determined for the year 2020 to comply with the level of production given in Senate Select Committee Print No. 8. This water demand was then prorated among the expected processing centers as shown in Table III-10.

Pulp and Paper Manufacture

Water demands for the pulp and paper manufacturing industry were calculated by using the mill locations and mill capacities outlined in Chapter I - Economic Projections.

Unit water use was estimated by using the following conversion factors: 1.75 cords of pulpwood per ton of wood pulp [13] and 35,000 gallons of water per ton of wood pulp.[14] Projected water demands for the pulp and paper manufacturing industry are given in Tables III-6 and III-11.

Table III-9

Projected Petrochemical Production Water Demands in the Study Area

Map Designation	General Area of Expansion	Cooling Water				
		Once thru Demand Per Ton of Prod. (gal.)	Demand with Recircula-tion (% of once thru)	Projected Demand (mgd)	Water for* Other Purposes (mgd)	Total Water Demand (mgd)
Kansas						
K-1	Garden City	84,000	5	19	12	31
K-8	Wichita	84,000	5	29	13	46
Oklahoma						
O-5	Ponca City	84,000	5	14	8	22
O-6	Tulsa	84,000	15	40	8	48
Texas						
T-2	Amarillo	84,000	5	32	18	25
T-3	Pampa-Borger	84,000	5	32	18	25
T-8	Wichita Falls	84,000	5	9	5	14
T-18	Longview-Marshall	84,000	15	92	19	111
Arkansas						
A-11	El Dorado	84,000	20	82	12	94
Louisiana						
L-1	Shreveport	84,000	20	125	18	143
L-3	Monroe	84,000	20	130	20	150

* Includes process, sanitary, and miscellaneous uses.

Table III-10

Projected Water Demands for the Gas Processing Industry in the Study Area

Map Designation	General Area of Expansion*	Projected Maximum Water Demand** (mgd)	% of Maximum Water Demand Required With More Extensive Reuse		Projected Water Demand*** (mgd)		
			Cooling Water	Misc. Water	Cooling Demand	Misc. Demand	Total Demand
Kansas							
K-1	Ulysses	54	5	3	3	1	4
K-4	Medicine Lodge	2	5	3			
K-8	Wichita	4	5	3	1		1
K-9	Attica	2	15	3	1		1
Oklahoma							
O-1	Hooker	23	5	3	2		2
O-2b	Elk City	10	5	3	1		1
O-3		1	5	3			
O-4	Covington	2	5	3			
O-5	Blackwell	10	15	3	2		2
O-6		2	15	3			
O-7	Chandler	4	10	3			
O-8	Oklahoma City	8	5	3	1		1
O-9	Lindsay	27	5	3	2		2
O-13	Healdton	3	15	3	1		1
O-14		3	15	3			
O-20		1	15	3			
Texas							
T-1	Sunray Dumas	73	5	3	4	2	6
T-2	Amarillo	8	5	3	1		1
T-3	Pampa-Borger	47	5	3	3	1	4
T-4b		1	5	3			
T-7	Knox City	1	5	3			
T-8		1	5	3			
T-9	Graham	1	15	3			
T-10	Springtown	15	15	3	2	1	3
T-11		2	15	3	1		1
T-14		1	15	3			
T-15	Van	1	15	3			
T-17		1	15	3			
T-18	Longview-Marshall	11	15	3	2		2
T-19	Carthage	25	15	3	3	1	4
Arkansas							
A-9	Stamps	1	20	3			
A-10	Magnolia	7	20	3	2		2
A-11	El Dorado	1	20	3			
Louisiana							
L-1	Cotton Valley	12	20	3	2	1	3
L-2	Ruston	5	20	3	1		1
L-3	Monroe	6	20	3	1		1
L-4	Waterproof	3	20	3	1		1

* Subareas with no particular areas of expansion listed have no significant demand centers.
** Includes little or no reuse.
*** Includes extensive reuse.

Table III-11

Projected Study Area Pulp and Paper Manufacturing and Water Demands

Map Designation	General Area of Expansion	Paper Mill Capacity No. of Plants/ Tons Per Day		2020 Water Demand (mgd)
		Actual 1958	Projected 2020	
Oklahoma				
O-16	Claremore	1/90	1/90	3.1
O-19a	Poteau		1/700	24.5
O-19b	Hugo		2/1,400	49.0
Texas				
T-12	Dallas-Ft. Worth	1/40	1/40	1.4
T-18	Marshall		1/800	28.0
Arkansas				
A-3	Van Buren		1/2,000	70.0
A-7	Little Rock	2/880	3/944	32.9
A-11	El Dorado	1/600	2/1,220	42.5
A-13	Crossett	1/655	1/655	22.9
Louisiana				
L-1	Shreveport	2/1,480	2/1,480	51.8
L-2	Ruston	1/580	1/580	20.3
L-3	Monroe	2/1,725	2/1,725	60.3
L-6	Alexandria		1/500	17.5

Primary Metals Output

Iron and Steel

It is assumed that water requirements per ton of iron and steel output will remain essentially unchanged. Table III-12 indicates expected conditions.

Table III-12

Present and Projected Study Area Iron and Steel Output

	Present		2020	
Location	Production Yearly (tons)	Water Use (mgd)	Production Yearly (tons)	Water Demand (mgd)
Pueblo, Colo.	1.3 million	75.6	4.26 million	248*
Lone Star, Tex.	0.8 million	10.2	2.62 million	33.4

* This is a once through demand. The plant manager at Pueblo states that by recirculating cooling waters and making use of ammonia liquors for quenching, they could triple capacity. The present company supply could then be utilized to meet the projected water demand. [15]

Source: Pueblo Chamber of Commerce [16]
Pueblo Regional Planning Commission [17]
Standard and Poors Corporation Records [18]

Aluminum

Water requirements in the production of alumina from bauxite are small. The industry average is approximately 0.66 gal. per pound of alumina. [19] Water requirements for reduction plants, however, are much higher. The industry average is 14.62 gal./lb. of aluminum. [19] To determine the projected water demand, a yearly production of 90 percent [20] of capacity was assumed and the average unit water demand used.

Table III-13 illustrates the water demands for the primary metals in the Arkansas-Red River basins in the year 2020.

Table III-13

Primary Metals Output Water Demands of the Arkansas-Red River Basins Study Area

Location	Type of Mill	2020 Water Demand (mgd)
Pueblo, Colorado	Steel	248
Lone Star, Texas	Steel	33.4
Arkadelphia, Ark.	Aluminum	12

Food and Kindred Products

The food and kindred products industry is one of the principal water-using industries of the United States. Its water requirements accounted for 5.6 percent of the total industrial water demand during 1954. Of this total, 50 percent was used for cooling and air conditioning and 25.5 percent for processing. 21/

Based on historical and current changes within the food and kindred products industry, certain assumptions were developed to govern projection of future water demands. These were:

1. Man-hour requirements per unit of production will be gradually reduced.
2. Upward trends in automation will increase water requirements per employee.
3. Other industries in which automation will increase water requirements will stabilize demand per unit of product by increased recirculation.
4. Water demand per unit of production is a more reliable basis for projection.
5. Rates of production projection, presented in Senate Select Committee Print No. 12, Table 2, "Domestic Requirements for Farm Products, 1954 and 1958, and projected for 1980 and 2000," would continue to the year 2020. 22/

Data presented in the 1958 Census of Manufactures provides the base for projection. This publication lists food and kindred plants by four digit Standard Industrial Classification (SIC) number, by location, and by size of employment. The nine food and kindred products subclasses are categorized by their water use significance in Tables III-14 and III-15.

Table III-14

Food and Kindred Products Industry Significant Water Use Classifications

SIC Subclasses	Product
2011-13-15	Meat and Poultry
2021-26	Milk, Cheese, Butter, Ice Cream, etc.
2031-37	Fruit, Vegetable, and Fish Processing
2061-63	Cane and Beet Sugar
2082-87	Alcoholic and Soft Beverage, etc.

Table III-15

Food and Kindred Products Industry Insignificant Water Use Classifications

SIC Subclasses	Product
2041-46	Grain Milling and Preparation
2051-52	Baked Goods
2071-73	Confectionary and Chewing Gum
2091-99	Oil Milling and Preparation

To determine the present water demands of the five selected subclasses, water departments and individual industries in the study area were contacted. Water demand for one or more years of record, types and quantities of products, and the number of employees were obtained. From these data, the water demand per unit of product and per employee was derived as shown on the following table.

Table III-16

Study Area Food and Kindred Products Industry Unit Water Demands

SIC	Gallons/employee/day	No. of Plants
201	356	9
202	245	8
203	336	6
206	2,400	1
208	1,820	4

SIC	Gallons/unit of production	No. of Plants
202	3 /gallon of milk	4
203	1.5/lb.	2
206	3,500 /ton	1
208	15 /case	4
2011-13	625 /head of cattle	2
2015	12 /bird	4

Water requirements of each of the food and kindred products industry significant subareas in the Arkansas-Red River basins are projected through the year 2020 using rates developed for the Senate Select Committee. The water demand is calculated by multiplying each projected production by the appropriate gallonage per unit of product. These individual water demands for the five subclasses are summed for each listed subarea under study. In these subareas, there is reason to believe a substantial portion of the food and kindred water demand is in excess of that included in the municipal projection. In addition, many of the food and kindred plants whose water demands are usually a part of the municipal demand are not included in the five SIC subclasses selected as significant water users. Taking these facts into consideration between 80 and 100 percent of the calculated water requirements is assumed to be the food and kindred industry water demands in excess of that reported as municipal.

Projected 2020 food and kindred water demands are given in Table III-17.

Table III-17

Projected Study Area Water Demands for Food and Kindred Products Production

Map Designation	Reference City	Projected 2020 Food and Kindred Products Water Demand (mgd)
Colorado		
C-1	Pueblo & Colo. Springs	1.5
C-4	Trinidad	4.0
Kansas		
K-7	Newton	0.2
K-8	Wichita	2.2
K-11	Emporia	1.7
K-12	Coffeyville	0.4
K-13	Pittsburg	0.8
Oklahoma		
0-4	Enid	0.4
0-5	Ponca City	0.9
0-8	Oklahoma City	1.9
0-15	Muskogee	0.8
0-6	Tulsa	1.9
Texas		
T-1	Dalhart	0.5
T-6	Plainview	0.1
T-11	Sherman	0.3
T-12	Dallas-Fort Worth	10.0
T-13	Paris	18.0
T-14	Greenville	0.8
Missouri		
M-1	Joplin	1.2
M-2	Aurora	2.7
Arkansas		
A-1	Fayetteville	6.0
A-3	Van Buren	4.5
A-4	Fort Smith	2.0
A-7	Little Rock	2.5
A-8	Stuttgart	0.3
Louisiana		
L-1	Shreveport	1.6
L-4	Tallulah	2.3
L-6	Alexandria	1.0

Projected Water Demands

Projected water demands for all industries are summarized in Table III-6 at the beginning of this section.

Agricultural Water Demands

Methodology

Since the principal agricultural water use in the study area is for crop irrigation, some basic assumptions were necessary in determining agricultural water use.

1. Agricultural water use will be secondary in priority to municipal and industrial water uses.
2. Rural residential and livestock water use, being comparatively minor and widespread, will be satisfied from ground water sources or small impoundments, and only water required for crop irrigation will be considered.
3. Projected irrigation will develop first along streams having a sufficient quantity of good quality water (electrical conductivity less than 1,000 micromhos).
4. All projected irrigation utilizing surface waters will be achieved by use of presently constructed or firmly committed projects and streambank pumping facilities operated by individuals.
5. Since much of the return flow from bank plant irrigation reenters surface streams via ground water aquifers in an undefinable manner, the effects of return flows from individual (non-project) irrigators are not assessed.

Irrigation water demands are derived from an examination of irrigated lands, irrigable lands, irrigated acreage projected to the year 2020, water requirements for crops, water quality of surface streams, and future agricultural efficiencies. These factors have been discussed previously in this appendix.

Projected Water Demands

Projection of irrigation water needs to be met by surface sources makes necessary the determination of the month during the irrigation season when critical conditions of high crop water requirements for the area revealed peak demands are generally exerted during the months of July and August. August is selected as the critical month, since streamflows usually average less than July. The assumption is that with sufficient water for irrigation during the month of August, adequate water would be available for irrigation during the rest of the season. Seasonal and August irrigation water requirements are shown in Tables III-18 and III-19, respectively.

Table III-18

Projected Annual Study Area Irrigation Water Requirements

Type-of-* Farming Area	Water Required By Plants (acre-inches/acre)	Efficiency of Application (percent)	Diversion Required (acre-inches/acre)
1	16	65	25
2	16	65	25
3	13	65	20
4	17	65	26
5	12	65	18
6	12	65	18
7	14	65	22
8	10	70	14
9	12	70	14
10	10	70	17
11	12	70	17

*These areas refer to Figure I-18 of this volume.

Table III-19

Projected August Study Area Irrigation Water Requirements

Type-of-Farming Area	Water Required By Plants (acre-inches/acre)	Efficiency of Application (percent)	Diversion Required (acre-inches/acre)
1	5	65	8
2	5	65	8
3	4	65	6
4	6	65	9
5	4	65	6
6	4	65	6
7	5	65	8
8	3	70	4
9	4	70	4
10	3	70	6
11	4	70	6

Efficiencies of application appearing in the above tables are farm efficiencies and do not apply to project type irrigation. These are the most probable efficiencies presented for the year 2000 by the Senate Select Committee.[23] Advancing technology in irrigation practices and improved management may make possible increased efficiencies in some areas; however, the efficiencies shown are assumed to represent average conditions expected in 2020.

Assuming that a reasonable allocation of waters to irrigation would result in no more than 50 percent depletion of projected mean August flows, sufficient supply will remain for other legitimate users. Projected quality assumptions provide for reduction in dissolved solids achieved by meeting water quality objectives described in Volume I of this appendix.

Total water demands projected for each type-of-farming area by source (ground and surface) are presented in Table III-20.

Table III-20

2020 Irrigation Water Requirements
(1,000 acre-feet annually)

Type-of-Farming Area	Water Source: Surface	Water Source: Ground	Total
1	1,060	190	1,250
2	120	3,450	3,570
3	30	220	250
4	150	430	580
5	50	20	70
6	70	60	130
7	80	40	120
8	130	30	160
9	270	50	320
10	250	510	760
11	1,220	710	1,930
TOTAL	3,430	5,710	9,140

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7. Federal Power Commission, Bureau of Power, "Report on Potential Consumptive Use of Fresh Water for Steam - Electric Generation by Public Utility Systems for the U.S. Study Commission - Texas," Fort Worth, Texas, Regional Office, June 1960.

8. U.S. Congress, Senate, Select Committee on National Water Resources, *Water Resources Activities in the United States*, Washington, Government Printing Office, August 1959.

9. Bureau of the Census, *Census of Manufactures, 1954*, Washington, Government Printing Office.

10. Report on conference with members of the Engineering Department of Phillips Petroleum Company, September 29, 1961.

11. *The Oil and Gas Journal*, "Air Cooling Saves for Sohio," April 6, 1959, (Volume 57, No. 15).

12. Walter Isard and Eugene Schooler, Location Factors in the Petrochemical Industry, U.S. Department of Commerce, (Publication 11640).

13. Forest Service, Timber Resources for America's Future, Forest Resource Report No. 14, Washington, Government Printing Office.

14. Personal correspondence from: I. James Pickl, Jr., Assistant Prof. of Economics, Southern Methodist University. Further substantiation by verbal contact with plant engineers of several mills in this area.

15. Reference, conference with Mr. H. H. Christi, plant manager of the CF&I Plant at Pueblo, Colorado in June 1961.

16. The Pueblo Chamber of Commerce, "What We Found in Colorado's Second Largest City," Pueblo, Colo., 1960.

17. Pueblo Regional Planning Commission, "Pueblo Regional Fact Book," Pueblo, Colorado, March 1961.

18. Standard and Poors Corporation Records, New York, September 14, 1961.

19. Geological Survey, Water Requirements of the Aluminum Industry, Washington, Government Printing Office, 1956, (Water-Supply Paper 1330-C).

20. Bureau of Mines, Minerals Yearbook, Volume 1, "Metals and Minerals," Washington, Government Printing Office, 1959.

21. U.S. Congress, Senate, Select Committee on National Water Resources, Water Resources Activities in the United States, Washington, Government Printing Office, (Print No. 8).

22. U.S. Congress, Senate, Select Committee on National Water Resources, Water Resource Activities in the United States, Washington, Government Printing Office, (Print No. 12).

23. U.S. Congress, Senate, Select Committee on National Water Resources, Water Resource Activities in the United States, Washington, Government Printing Office, (Print No. 12).

24. "Irrigation Water Requirements," estimates by the Bureau of Reclamation, using the Lowry-Johnson consumptive use computation adjusted for effective precipitation.

25. Texas Board of Water Engineers, Consumptive Use of Water by Major Crops in Texas, November 1960 (Bulletin 6019).

IV. PLANS FOR SUPPLYING FUTURE MUNICIPAL AND INDUSTRIAL WATER SUPPLY REQUIREMENTS

Assumed plans for supplying all of the projected municipal and industrial water requirements detailed previously in Table III-6 to the year 2020 are summarized by subareas in Table IV-1. These plans (as of August 1962) satisfy projected 2020 requirements by use of existing sources, committed water supply storage in Federal, municipal, and State projects, either under construction or for which construction funds have been approved, water from the Arkansas and Red Rivers above and below the reaches to be affected by the quality improvement, and other sources of water supply within or near the study area. In some subareas, it was not feasible to satisfy two or more localities having large future requirements by a single plan. In these subareas, needs are divided, and separate requirements and potential sources of supply are presented for each of the projected demand areas within the major subarea.

In subareas where firm yields from present and firmly committed sources of water supply do not meet or exceed the projected municipal and industrial water requirement, potential sources were assumed to satisfy the unmet 2020 needs. The water supply plans presented in Table IV-1 are assumed to be the most likely alternatives in estimating the value of benefits to municipal and industrial uses which would accrue with improvement of water quality, in areas affected by mineral pollution. It is pertinent to point out, however, that these plans, as devised, are based on present knowledge of surface and ground water yields and costs incurred in water supply development and transmission of water. As a more detailed study is made in these areas, new and better plans may be devised. Information regarding the availability and firm yields of ground water (the most widely available source of water supply in the study area) is limited. Ground water has been considered as a source of future water supply only in areas where firm yields are indicated and where capable of meeting part of or all of the projected requirement at reasonable cost.

Table IV-1

Assumed Plans for Meeting 2020 Study Area Municipal and Industrial Water Requirements
(all quantities in mgd)

State - Area Designation	2020 Water Requirements M & I High Quality Water	 Industrial Cooling Water	 Total	Present Sources - Yields a/		Committed Sources - Yields		Potential Sources With Water of Suitable Quality Available in Affected Stream Reaches Sources	 Yield	 Without Water of Suitable Quality Available in Affected Stream Reaches b/ Sources	 Yield
Colorado											
Pueblo - Colo. Springs	131	58	189	Surface Water	93				298		298
								Eagle River	63	Eagle River	63
								Frying Pan Project	9	Frying Pan Project	9
								Other Surface West Slope Waters		Other Surface West Slope Waters	
								Additional Surface & Ground Water Supplies	226	Additional Surface & Ground Water Supplies	226
Lamar	7	2	9	Ground Water	29						
Canon City	8	2	10		11						
				Surface Water	9						
				Ground Water	2						
Trinidad	14	3	17		26						
				Surface Water	10						
				Ground Water	16						
New Mexico											
Raton	8	2	10		8			Ground Water	2		
				Surface Water	6						
				Ground Water	2						
Clayton	14	4	18	Ground Water	16			Ground Water	[illegible]		
Kansas											
Garden City	47	68	115	Ground Water	73				52		
								Ground Water			
								Surface Water			
Larned	4	1	5	Ground Water	4						
Dodge City	10	2	12	Ground Water	5			Ground Water	7		
Medicine Lodge	4	0	4	Ground Water	8						
Pratt	7	2	9	Ground Water	17						
Great Bend	16	0	17	Ground Water	19			Ground Water	1		
Newton	21	12	33		18				15		
				Surface Water	1			Smoky Hill Res.			
				Ground Water	17			Ground Water			
Wichita*	364	133	497								
City of Wichita and Environs	274	105	379	Ground Water	96	Cheney Res.	30	Arkansas River	[illegible] c/	Arkansas River	[illegible] d/
								Gar Res.	[illegible]	Gar Res.	[illegible]
Hutchinson	26	0	26	Ground Water	18			Ground Water	4		
								Arkansas River	4		
Other Municipalities	60	33	93		13						
				Ground Water	10			Surface Water	33		
				Surface Water	3			Walnut River	29		
								Ground Water	21		
Wellington	8	3	11		8			Ground Water	3		
				Surface Water	3						
				Ground Water	5						
Eureka	5	2	7		3				4		
				Surface Water	2			Toronto Res.			
				Ground Water	1			Fall River Res.			
								Neosho River and Lake Kahola			
								Ground Water			
Emporia	13	44	57		26				31		
				Surface Water	19			Toronto Res.			
				Ground Water	7			Fall River Res.			
								Neosho River and Lake Kahola			
								Ground Water			
Coffeyville	15	30	45	Surface Water	12				33		
								Verdigris River			
								Big Hill Res.			
								Toronto Res.			
								Fall River Res.			
								Elk City Res.			
Pittsburg	5	1	6	Ground Water	4			Ground Water	2		

a/ See Table III-1 for the itemized breakdown of these data.
b/ Potential sources for these areas not affected by the improvement in water quality are the same as shown in the adjoining column and are therefore not listed.
c/ Based on the use of a 30 mgd offstream storage reservoir for distribution of flows.
d/ Based on the use of a 55 mgd offstream storage reservoir for distribution of flows.
e/ Source of industrial cooling water.
* Areas which could use improved quality water from affected stream reaches if available.

Table IV-1 (Continued)

Proposed Plans for Meeting 2020 Study Area
Municipal and Industrial Water Requirements
(all quantities in mgd)

State - Area Designation	2020 Water Requirements: M & I High Quality Water	Industrial Cooling Water	Total	Present Sources - Yields a/		Committed Sources - Yields		Potential Sources: With Water of Suitable Quality Available in Affected Stream Reaches: Source	Yield	Without Water of Suitable Quality Available in Affected Stream Reaches b/: Source	Yield
Oklahoma											
Guymon	8	2	10	Ground Water	11						
Woodward	6	2	8	Ground Water	12						
Clinton	16	5	21	 Surface Water Ground Water	16 4 13	Foss Res.	18				
Alva	5	2	7	Ground Water	12						
Enid	23	12	35	Ground Water	15			 Ground Water Canton Res.	28		
Ponca City	19	42	61	 Surface Water Ground Water	36 15 21			Kaw Res. c/	43		
Tulsa*	265	307	572								
City of Tulsa and Vicinity	170	307	477	Surface Water	132	Oologah Res.	67	Keystone Res.	300	Keystone Res. Oologah Res.	3[illegible] d/ 93
Bartlesville	27		27	Surface Water	15			[illegible] Res.	12	[illegible] Res.	12
Other Municipalities	2		2	 Ground Water Surface Water	56 6 50						
Stillwater	29	21	50	 Surface Water Ground Water	26 19 7			 Surface Water Ground Water	26		
Oklahoma City*	318	80	398	 Surface Water Ground Water	111 64 47	 Arcadia Res. Norman Res.	71 45 26	Keystone Res.	216	Tuskahoma Co.	216
Duncan*	39	30	69								
City of Duncan	18	30	48	Surface Water	7			Red River	41	[illegible] Res.	41
Other Municipalities	21		21	 Surface Water Ground Water	23 10 13						
Lawton*	47	13	60	Surface Water	11	Cache Creek Res.	6	Red River	40	Waurika Res.	40
Altus	8	2	10	Surface Water	7			Mountain Park Res.	3		
Frederick	7	4	11	 Surface Water Ground Water	3 2 1			Ground Water	4		
McAlester*	15	10	25	 Surface Water Ground Water	7 6 1			Lake Texoma	18	Arbuckle Res.	18
Shawnee	27	8	35	 Surface Water Ground Water	30 17 13			Ground Water	9		
Muskogee	25	29	54	Surface Water	61						
Claremore	14	5	19	Surface Water	12			Oologah Res.	12		
Miami	8	4	12	 Surface Water Ground Water	10 2 8			Ground Water	2		
[illegible]	8	2	10	Surface Water	8			Ground Water	2		
[illegible]*	32	3	35	Surface Water	7			Arkansas River	28	[illegible] Creek Res. Arkansas River	25 3
Hugo	57	3	60	 Surface Water Ground Water	148 146 2						
Durant	12	4	16	Surface Water	8			Local Surface and Ground Water	8		

a/ See Table III-1 for the itemized breakdown of these data.
b/ Potential sources for these areas not affected by the improvement in water quality are the same as shown in the adjoining column and are therefore not listed.
c/ Source of industrial cooling water.
* Areas which could use improved quality water from affected stream reaches if available.

Table IV-1 (Continued)

Assumed Plans for Meeting 2020 Study Area
Municipal and Industrial Water Requirements
(all quantities in mgd)

[illegible]

[illegible]

V. BENEFITS OF WATER QUALITY IMPROVEMENT

General

Portions of the study area in both basins are directly affected by the water quality degradation resulting from natural brine discharges. These areas lie in the middle Arkansas-Red River basins, adjacent to the main stems and various tributaries, as shown on Figure V-1.

Improvement in the water quality in these reaches to meet the 100 mg/l chloride concentration criteria described in Volume I of this Appendix, will result in these waters being available for various legitimate uses, such as for municipal, industrial, and agricultural purposes.

The following tangible benefits will be realized from this water quality improvement:

1. Water supply of suitable quality for municipal use will be physically more convenient and obtainable at lower costs from nearby streams and reservoirs.
2. Industries requiring large quantities of high quality water will have an abundant supply available adjacent to low cost water transportation.
3. Irrigation will be possible at reasonable cost in areas adjacent to affected stream reaches in both basins.
4. Availability of water of suitable quality from previously salt degraded streams will alleviate water shortages such as occurred during the 1950's.

Evaluation of Benefits

Realization of the benefits from control of natural brine discharges is dependent upon success of pollution abatement programs in the Arkansas-Red River basins. Good progress has been made toward control of municipal, industrial, and oilfield brine pollution in both river basins. However, the effectiveness of these activities in providing waters of suitable quality for all legitimate uses is curtailed by the consequences of natural pollution. Evaluation of benefits from a program to abate natural brine pollution is based upon its part in achieving overall goals of water quality criteria for optimum resource development in these basins.

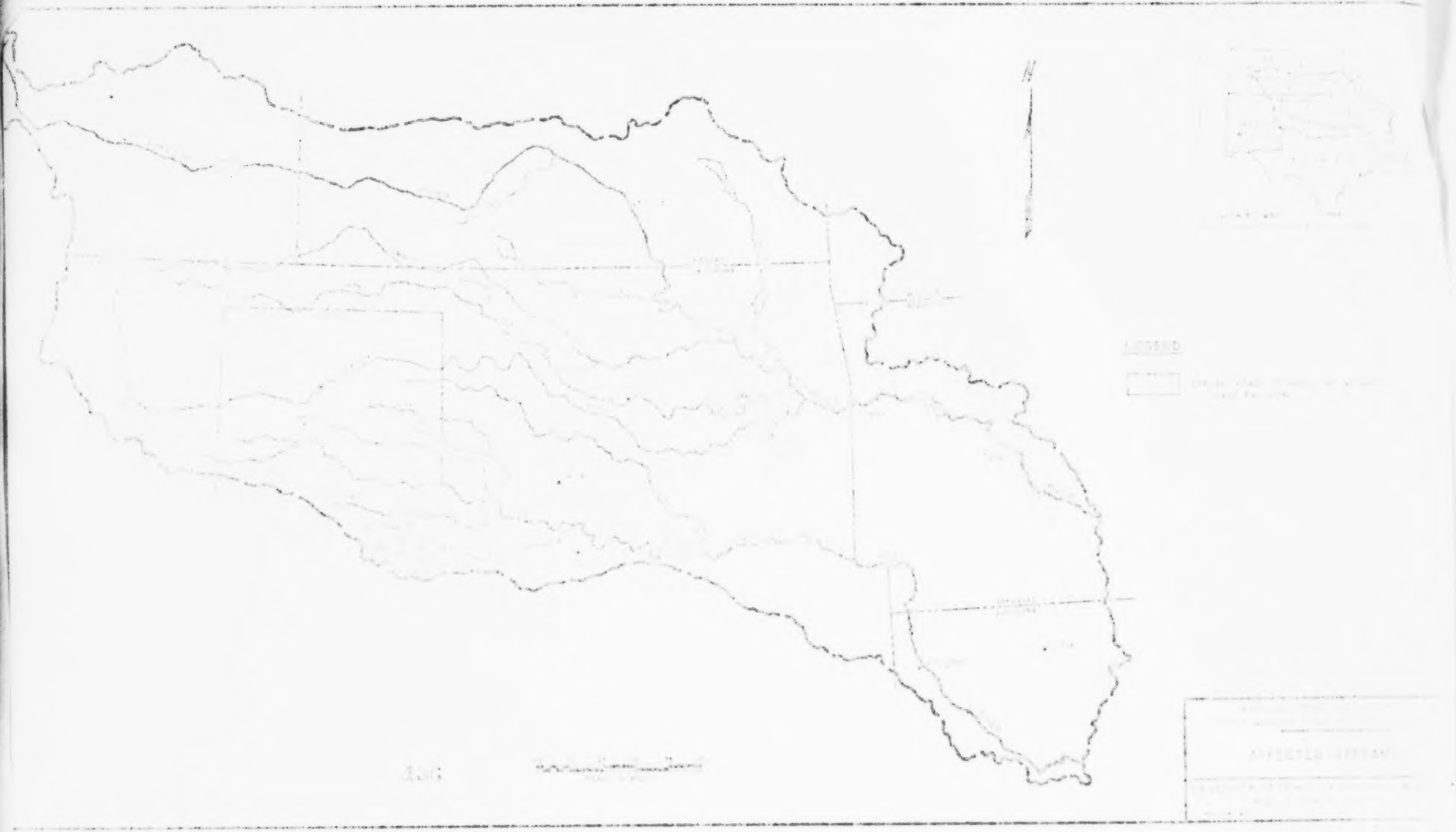
Methods of Evaluation

Projected 2020 municipal, industrial, and agricultural water requirements for the Arkansas and Red River systems form the basis from which the value of benefits attributable to water quality improvement can be derived. As shown in Table IV-1, there are 13 areas within the two river systems which could use water from affected streams if the quality were improved so as to be suitable for municipal, industrial, and agricultural water supply purposes. Provision of suitable quality water in these areas would contribute to more economical and effective use of water within the basins. To derive the net value of the benefits of water quality improvement, the following methods were employed.

The value of the benefits to municipal and industrial water uses was computed by the alternative cost method permitted by Senate Document No. 97. The document states that municipal and industrial water supply benefits are based on improvements in quantity, quality, dependability, and physical convenience of water use. In regard to the value of these benefits the document states:

> "The amount water users should be willing to pay for such improvements in lieu of foregoing them affords an appropriate measure of this value. In practice, however, the measure of the benefit will be approximated by the cost of achieving the same results by the most likely alternative means that would be utilized in absence of the project." (In this evaluation "project" should be interpreted as improvement in water quality to meet water quality objectives discussed in Volume I of this Appendix, i.e., 100 mg/l chloride concentration in affected streams.)

The values of municipal and industrial water supply benefits determined for the projected 2020 level of water needs are therefore the combined costs of storage, transmission, and treatment of water from the most likely alternative source less the total cost of obtaining water of suitable quality from reaches of the streams which will be affected by water quality improvement. This is illustrated in the following analysis of value estimation for the Oklahoma City subarea.


N
LEGEND
AFFECTED STREAM

Estimation of Value of Benefits for the Oklahoma City Subarea

Plan A

Using potential alternate water supply source in absence of water quality improvement in affected stream reaches

Source	Tuskahoma Reservoir
Total Municipal and Industrial Water Requirements (including cooling water)	215 mgd
Year of First Need	1985
Capital Cost of Reservoir to Yield 215 mgd in Year of First Need	$8,020,000 [1]
Operation and Maintenance Cost	$40,000 per year [2]

Step 1

Capitalized Worth of All Operation & Maintenance (Figure V-2, Detail b) In the Year of First Need

$40,000 x 30.6312 [3]	$ 1,225,000

Step 2

Costs of Transmission to Supply Projected Municipal and Industrial Water Needs to the Year 2020 (Figure V-2, Detail c)

---

[1] Based on estimated unit costs per 1,000 gallons provided by the Corps of Engineers.

[2] Estimated as 0.5 percent of the initial construction cost.

[3] Factor to determine the capitalized value or present worth of an annuity of one (1) per year from the year of first need (1985) to 2070 using interest rate of 3 percent.

Transmission Distance . . . 162 miles
Transportation Cost/1,000
gallons . . 162 x $0.00075 4/. . . $ 0.122
Capitalized Annual Cost in 2020-
215 mgd x 365 x $0.122 . . . . . . $ 9,574,000

Capitalized Worth in the Year
of First Need

$\frac{\$9,574,000}{35}$ x 323.1138 5/ $88,385,000

Step 3

Costs of Transmission to Supply the Projected Municipal and Industrial Water Needs in the Year 2020 to the Year 2070 (Figure V-2, Detail c)

Capitalized Worth in 2020

$9,574,000 x 25.7298 6/ $246,337,000

Worth Discounted to the Year
of First Need

$246,337,000 x 0.35538 7/ . . . . . $ 87,543,000

Step 4

Total Costs Using Plan A (Figure V-2, Details a, b, and c)

Capitalized Worth in Year of First Need:

of Reservoir.	$ 8,020,000
of Operation & Maintenance. . . .	$ 1,225,000
of Transmission to 2020	$ 88,385,000
of Transmission After 2020. . . .	$ 87,543,000

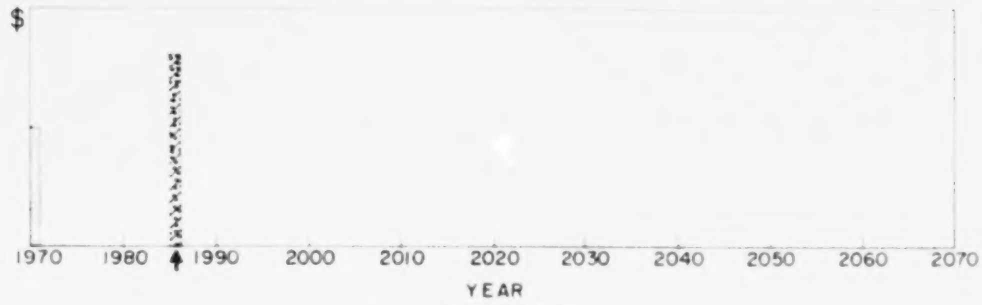
4/ Based on standard curves developed for the office of Saline Water Conversion - Reference: U.S. Department of the Interior, Office of Saline Water Conversion, Disposal of Saline Water Conversion Brines, Louis Koenig, Figure 4 - 5.

5/ Factor to determine the capitalized value or present worth of an increasing annuity from the year of first need (1985) to 2020 using 3 percent interest rate.

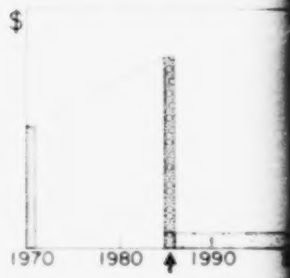
6/ Factor to determine the capitalized value or present worth of an annuity of one (1) per year from 2020 to 2070 using 3 percent interest rate.

7/ Factor to determine the worth in the year of first need (1985) by discounting the capitalized value in 2020 at 3 percent interest rate back to 1985.

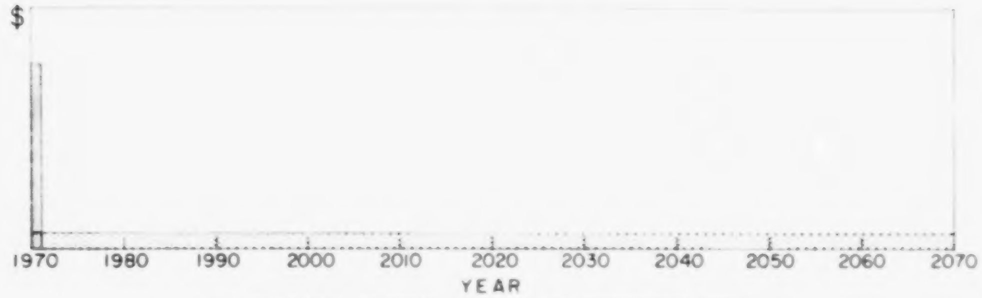
VALUE OF M



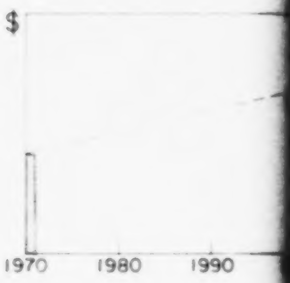
a. CAPITAL COST



b. RESE

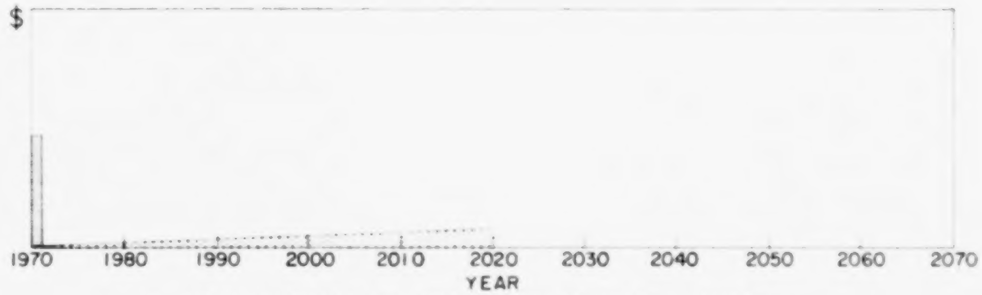


d. AVERAGE ANNUAL VALUE OF BENEFITS FOR 100 YEARS PERIOD AT 3% INTEREST



e. 1970 W

VALU



g. 1970 CAPITALIZED WORTH OF 1970-2020 VALUES

h. 1970 CA

LEGEND

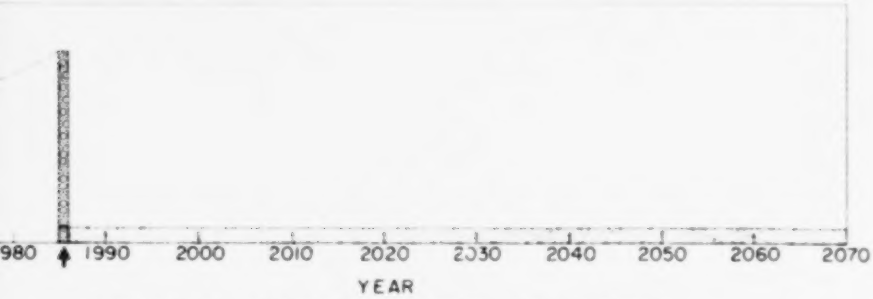
▭ 1970 CAPITALIZED WORTH

▨ CAPITALIZED VALUE OF AN INCREASING ANNUITY IN THE YEAR INDICATED

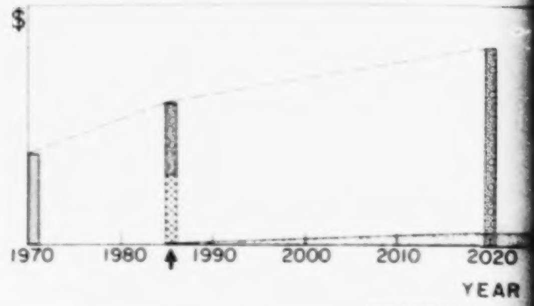
┈ TIME SERIES ANNUAL VALUE

▭ ANNUAL COST

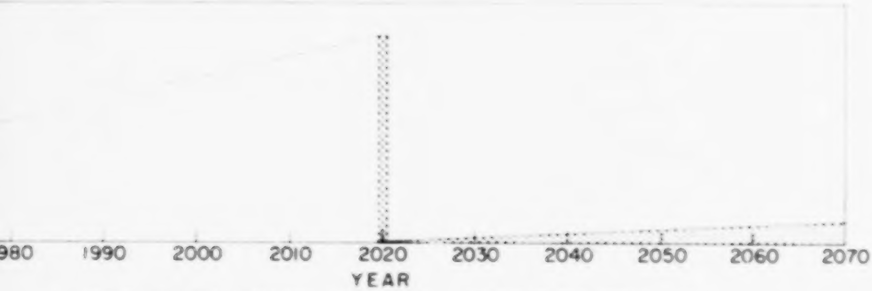
LUE OF MUNICIPAL AND INDUSTRIAL BENEFITS --- NO SCALE



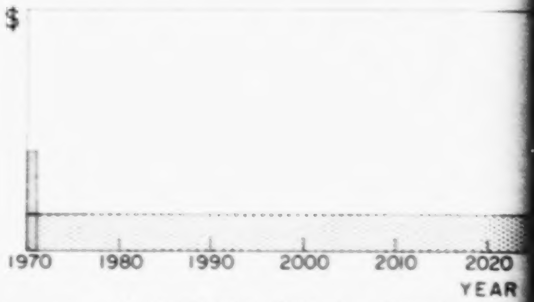
b. RESERVOIR OPERATION AND MAINTENANCE COST



c. TRANSMISSION

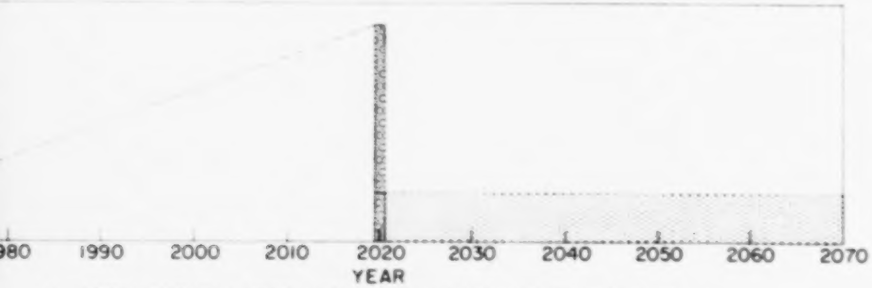


e. 1970 WORTH VALUE OF 2020 – 2070 BENEFITS

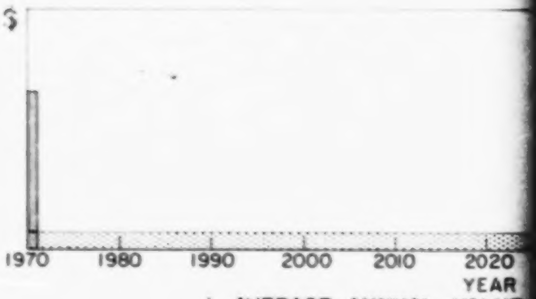


f. AVERAGE ANNUAL VALUE OF 2
100 YEARS PERIOD AT

VALUE OF AGRICULTURAL BENEFITS --- NO SCALE



h. 1970 CAPITALIZED WORTH OF 2020 – 2070 VALUES



i. AVERAGE ANNUAL VALUE
100 YEARS PERIOD AT

LEGEND

SING

▨ CAPITALIZED VALUE OF A 3% ANNUITY IN THE YEAR INDICATED

▩ CAPITAL COST IN THE YEAR INDICATED

↑ YEAR OF FIRST NEED

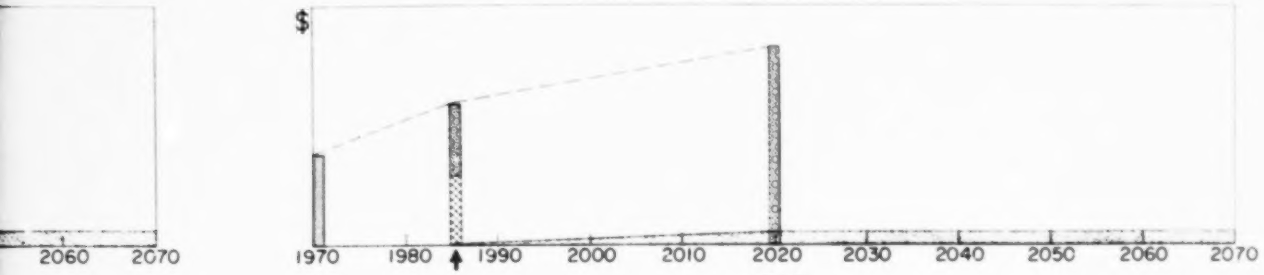
----- DISCOUNT AT 3% TO WORTH IN YEAR INDICATED

139

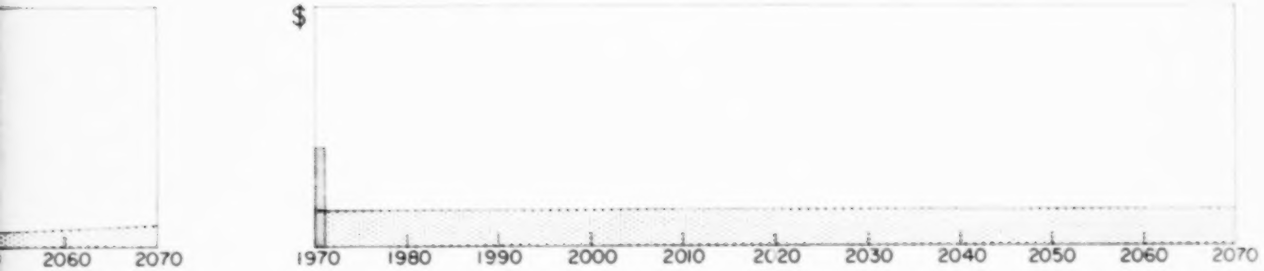
U.S

B

NEFITS --- NO SCALE

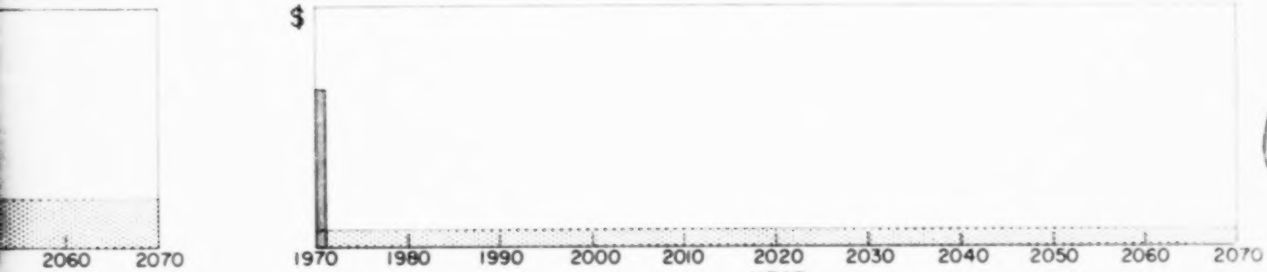


c. TRANSMISSION COST



f. AVERAGE ANNUAL VALUE OF 2020 — 2070 BENEFITS FOR 100 YEARS PERIOD AT 3% INTEREST

--- NO SCALE



i. AVERAGE ANNUAL VALUE OF BENEFITS FOR 100 YEARS PERIOD AT 3% INTEREST

C

↑ YEAR OF FIRST NEED

D

----- DISCOUNT AT 3% TO WORTH IN YEAR INDICATED

ARKANSAS – RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

TIME SERIES VISUALIZATION
OF VALUE OF WATER QUALITY
IMPROVEMENT BENEFITS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE V-2

Total Capitalized Worth in
the Year of First Need $185,173,000

1970 Value of Plan A

$185,173,000 x 0.64186 [8] $118,855,000

Plan B

Using Potential Water Supply Source in the Area of Water Quality Improvement

Source . . . . Keystone Reservoir

Total Municipal and Industrial Water Requirements
(including cooling water). . . . . . 215 mgd

Year of First Need 1985

Capital Cost of Reservoir to
Yield 215 mgd . . . . $ 18,250,000 [1]

Operation & Maintenance Cost . . . . $ 91,250 per year [2]

Step 1

Capitalized Worth of All Operation & Maintenance (Figure V-2, Detail b) in the Year of First Need

$91,250 x 30.6312 [3] . . . . $ 2,795,000

Step 2

Costs of Transmission to Supply Projected Municipal and Industrial Water Needs to the Year 2020 (Figure V-2, Detail c)

---

[1] Based on estimated unit costs per 1,000 gallons provided by the Corps of Engineers.

[2] Estimated as 0.5 percent of the initial construction cost.

[3] Factor to determine the capitalized value or present worth of an annuity of one (1) per year from the year of first need (1985) to 2070 using interest rate of 3 percent.

[8] Factor to determine the worth in 1970 by discounting the value in the year of first need (1985) using 3 percent interest rate back to 1970.

Transmission Distance . . . 85 miles
Transportation Cost/1,000
gallons . . 85 x $0.00075 [4] . . . $ 0.0638
Annual Cost in 2020-
215 mgd x 365 x $0.0638 . . . . . $ 5,007,000

Capitalized Worth in the Year of First Need

$\frac{\$5,007,000}{35}$ x 323.1138 [5] . . . . . $ 46,224,000

Step 3

Costs of Transmission to Supply the Projected Level of Municipal and Industrial Water Need in the Year 2020 to the Year 2070 (Figure V-2, Detail c)

Capitalized Worth in the Year 2020

$5,007,000 x 25.7298 [6]. $128,829,000

Worth discounted to the Year of First Need

$128,829,000 x 0.35538 [7] . . . . . $ 45,783,000

Step 4

Total Costs Using Plan B (Figure V-2, Detail a, b, and c)

Capitalized Worth in Year of First Need:	
Reservoir	$ 18,250,000
Operation & Maintenance	$ 2,795,000
Transmission to 2020.	$ 46,224,000
Transmission After 2020	$ 45,783,000

---

[4] Based on standard curves developed for the office of Saline Water Conversion - Reference: U.S. Department of the Interior, Office of Saline Water Conversion, Disposal of Saline Water Conversion Brines, Louis Koenig, Figure 4 - 5.

[5] Factor to determine the capitalized value or present worth of an increasing annuity from the year of first need (1985) to 2020 using 3 percent interest rate.

[6] Factor to determine the capitalized value or present worth of an annuity of one (1) per year from 2020 to 2070 using 3 percent interest rate.

[7] Factor to determine the worth in the year of first need (1985) by discounting the capitalized value in 2020 at 3 percent interest rate back to 1985.

Capitalized Cost or Value in the Year of First Need	$113,052,000
1970 Value of Plan B $113,052,000 x 0.64168 [8]. . . .	$ 72,543,000

Step 5

Value Differential

	Water Treatment Cost	Storage and Transmission Cost	Total Cost
Plan A	[9]	$118,855,000	$118,855,000
Plan B	[9]	$ 72,543,000	$ 72,543,000
Net Value of Water Quality Improvement			$ 46,312,000

Step 6

Value of Benefits

1970 Capitalized Worth of Benefits to Supplying the Projected 2020 Level of Municipal and Industrial Water Needs in the Oklahoma City Area Using Plan B (Figure V-2, Detail d)	$ 46,312,000
Average Annual Value for 100 Years @ 3 percent (Figure V-2, Detail d) $46,312,000 x 0.031646 [10]	$ 1,466,000

Values of municipal and industrial water supply benefits were determined for the remaining areas on a similar basis. Summaries of the individual steps taken in the analysis are shown in Table V-1. As shown by the water supply plan on Table IV-1, projected industrial cooling water needs in most of the potential benefit areas can be met by use of water from the Arkansas and Red Rivers regardless of water quality improvement. Exceptions will occur when cooling water can be obtained more economically from other sources or from a combined municipal and industrial water supply system.

The decision to forego evaluation of benefits for improving quality to meet projected cooling water demands was based on findings in a special Public Health Service study of water quality requirements in the use of industrial cooling waters. In the course of the study, letters were circulated to manufacturing companies practicing recirculation of cooling water with high chloride and dissolved solids levels and consulting laboratories specializing in industrial

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[8] Factor to determine the worth in 1970 by discounting the value in the year of first need (1985) using 3 percent interest rate back to 1970.

[9] The difference in cost of water treatment using the source in Plan A or Plan B is insignificant.

[10] Factor to determine the annuity for 100 years, associated with the 1970 capitalized value of benefits, using 3 percent interest rate.

Table V-1

Summary of Estimates -- Value of Benefits to Serving Projected 2020 Municipal and Industrial Water Needs - Resulting From Improvement in Water Quality -- Arkansas and Red River Basins
(all dollar values in thousands)

			Water Supply Storage Costs						Water Transmission Costs						Total Costs - Storage and Transmission		Value of Benefits		
							Step 1				Step 2		Step 3		Step 4		Step 5	Step 6	
Basin - Area Designation	Plan	2020 High Qual. Water Req. a/ (mgd)	Source* of Supply	First Need (yr.)	Cap. Cost b/ ($)	Annual Operation & Maintenance Cost c/ ($)	Cap. Worth O & M Cost d/ ($)	Amt. of Water to be Transported (mgd)	Est. Trans. Dist. e/ (mi.)	Cost/ 1,000 Gals. (¢)	Annual Trans. Cost in 2020 f/ ($)	Capital Worth in Year of First Need g/ ($)	2020 Cap. Worth of 2020 to 2070 Costs h/ ($)	Capital Worth in Year of First Need g/ ($)	Capital Worth in Year of First Need g/ ($)	1970 Cap. Worth i/ ($)	1970 Cap. Worth i/ ($)	Avg. Ann. Value of Benefits Over 100 Yrs.@ 3% j/ ($)	2020 Value k/ ($)
Arkansas R.																			
Wichita	A	140	Arkansas R.	1975				---	---	---	---	---	---	---	---	---			
	A		Kaw Res.		21,990	118.0	3,696	140	45	4.50	2,300	22,747	59,178	15,669	84,082	55,278			
	B		Arkansas R.		---	---	---	---	---	---	---	---	---	---	---	---	18,517	587	1,136
	B		Kaw Res.		14,960	95.3	2,985	72	45	5.63	1,480	14,401	38,080	10,070	42,616	36,761			
Tulsa	A	93	Oologah Res.	1995	17,550	115.0	3,416	93	12	1.30	407	3,254	10,472	5,082	29,222	13,937			
	A		Keystone Res.		5,370			---	---	---	---	---	---	---	5,370	2,565	2,349	81	296
	B		Keystone Res.		25,670	127.3	3,783	---	---	---	---	---	---	---	29,253	13,972			
Okla. City	A	135	Tuskahoma Res.	1985	8,030	40.0	1,225	215	162	12.20	9,374	88,385	246,337	87,543	185,173	118,855	46,312	1,466	4,119
	B		Keystone Res.		18,230	91.3	2,795	215	85	6.38	5,007	46,205	128,830	45,784	113,034	72,552			
Poteau	A	25	Arkansas R.	1970	---	---	---	---	---	---	---	---	---	---	---	---			
	A		Brazil Cr.		1,780	18.0	569	---	---	---	---	---	---	---	2,349	2,349	2,349	74	101
	B		Arkansas R.		---	---	---	---	---	---	---	---	---	---					
Ft. Smith - Van Buren	A	83	Arkansas R.	1970	---	---	---	---	---	---	---	---	---	---	---	---			
	A		Tributary Development		5,900	29.5	932	---	---	---	---	---	---	---	6,832	6,832	6,832	216	260
	B		Arkansas R.		---	---	---	---	---	---	---	---	---	---	---				
SUBTOTAL		676																2,424	5,910

a/ Total 2020 high quality water requirement in excess of existing sources.
b/ Capital cost of reservoir to supply yield needed.
c/ Annual Operation and maintenance cost.
d/ Capitalized Worth operation and maintenance costs in year of first need.
e/ Estimated transmission distribution.
f/ Annual transmission cost in 2020.

g/ Capitalized worth in year of first need.
h/ 2020 Capitalized worth of 2020 to 2070 transmission costs.
i/ 1970 capitalized worth.
j/ Average annual value over 100 years at 3 percent.
k/ Annual cost of meeting 2020 needs in 2020 (Value of benefits in 2020).
* See Water Supply Plan - Table IV-1.

Table V-1 (Continued)

			Water Supply Storage Costs					Water Transmission Costs							Total Costs - Storage and Transmission		Value of Benefits		
							Step 1				Step 2		Step 3		Step 4		Step 5	Step 6	
Basin - Area Designation	Plan	2020 High Qual. Water Req. a/ (mgd)	Source* of Supply	First Need (yr.)	Cap. Cost b/ ($)	Annual Operation & Maintenance Cost c/ ($)	Cap. Worth O & M Cost d/ ($)	Amt. of Water to be Transported (mgd)	Est. Trans. Dist. e/ (mi.)	Cost/ 1,000 Gals. (c)	Annual Trans. Cost in 2020 f/ ($)	Capital Worth in Year of First Need g/ ($)	2020 Cap. Worth of 2020 to 2070 Costs h/ ($)	Capital Worth in Year of First Need g/ ($)	Capital Worth in Year of First Need g/ ($)	1970 Cap. Worth i/ ($)	1970 Cap. Worth i/ ($)	Avg. Ann. Value of Benefits Over 100 yr.@ 3% j/ ($)	2020 Value k/ ($)
Red River																			
Duncan	A	15	Hennepin Res.	1970	16,987	150.0	6,760	45	35	5.25	862	8,675	22,179	5,059	33,461	33,461	23,036	749	905
	B		Red Riv.		---	---	---	45	25	3.75	616	6,189	15,850	3,616	9,805	9,805			
Lawton	A	29	Waurika	1975	17,625	176.3	5,521	42	26	3.90	598	5,921	15,386	4,080	33,126	28,583	16,985	338	509
	B		Red River		---	---	---	42	33	5.25	805	7,968	20,712	5,677	13,445	11,598			
Wichita Falls	A	27	Lake Kemp	1990	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
	A		Ringgold Res.		9,800	40.0	1,680	27	22	4.30	424	3,660	10,909	4,494	19,456	10,771	10,771	341	834
	B		Red River		---	---	---	---	---	---	---	---	---	---	---	---	---		
	B		Lake Kemp		---	---	---	---	---	---	---	---	---	---	---	---	---		
Ardmore	A	7	Arbuckle Res.	1970	5,350	54.0	1,706	18	18	4.16	256	2,566	6,507	1,503	11,125	11,125	6,205	196	267
	B		Lake Texoma		512	l/		18	17	3.90	272	2,717	6,998	1,596	4,025	4,025			
Sherman - Denison	A	19	Boswell Res.	1970	1,015	l/		19	50	11.50	800	8,051	20,506	4,005	13,761	13,761			
	A		Lake Texoma		426	l/		12	10	2.80	123	1,240	3,165	722	2,388	2,388	11,786	373	729
	B		Lake Texoma		1,113	l/		31	30	1.80	204	2,053	5,269	1,197	4,363	4,363			
Dallas - Ft. Worth	A	490	Boswell Res.	1990	26,690	l/		532	70	3.50	6,796	50,230	176,859	72,060	157,968	87,464			
	A		Tenn. Colony Res.		69,720	l/		263	90	6.30	6,048	52,714	155,614	66,111	166,525	92,202	136,191	4,245	11,576
	B		Lake Texoma		37,130	l/		793	34	0.98	2,850	26,791	73,330	30,211	82,132	65,675			
Shreveport	A	100	Red River	1980	---	---	---	---	---	---	---	---	---	---	---	---			
	A		Off-Stream Storage		---	---	---	25	3	0.60	55	539	1,615	436	973	724	724	23	55
	B		Red River		---	---	---	---	---	---	---	---	---	---	---	---			
Alexandria	A	40	Red River	1970	---	---	---	---	---	---	---	---	---	---	---	---			
	A		Iatt Lake		753	l/	---	---	---	---	---	---	---	---	753	753	753	19	23
	B		Red River		---	---	---	---	---	---	---	---	---	---	---				
SUBTOTAL		735																6,484	14,979
TOTAL		1,211																8,908	20,886

a/ Total 2020 high quality water requirement in excess of existing sources.
b/ Capital cost of reservoir to supply yield needed.
c/ Annual operation and maintenance cost.
d/ Capitalized worth operation and maintenance costs in year of first need.
e/ Estimated transmission distribution.
f/ Annual transmission cost in 2020.

g/ Capitalized worth in year of first need.
h/ 2020 capitalized worth of 2020 to 2070 transmission costs.
i/ 1970 capitalized worth.
j/ Average annual value over 100 years at 3 percent.
k/ Annual cost of meeting 2020 needs in 2020 (Value of benefits in 2020).
l/ Included in reservoir costs.
* See Water Supply Plan - Table IV-1.

water problems. In addition, discussions were held with representatives of power companies and power plant consultants. A review was made of available published data on cooling tower construction and operation, with particular emphasis on cooling water recirculation and treatment. Findings in the Public Health Service survey revealed that in some locations industry currently utilizes sea water for cooling purposes. The study further revealed that the presence of dissolved chlorides in recirculating cooling systems (particularly in the range from 100 to 2,000 mg/l), induces no appreciable increase in costs of the following items: Initial construction and maintenance, operation, and water treatment.

The chloride concentration in industrial cooling waters appears to be of significance only in its contribution to dissolved solids, which is the usual governing factor in determining permissible number of cycles and the frequency of blowdown. In view of these findings, it is felt that the anticipated reductions of chloride ion concentration in waters which could be used for cooling water purposes in the Arkansas and Red River systems would be of insignificant benefit to industry.

As indicated in previous sections, projected 2020 water demands for the study area are 4.94 bgd for municipal and industrial process purposes. Based on the total study area population, overall unit demands for these uses are approximately 200 gpcd. Assuming that municipal and industrial demands will be closely related to the total population, and the overall unit demand will be unchanged, the 2070 study area municipal and industrial requirements, exclusive of cooling water, are expected to average 8.4 bgd.

No increase is anticipated for irrigation between 2020 and 2070; therefore, irrigation water use is expected to remain approximately the same, or possibly be reduced, because of higher efficiencies of agricultural water use.

Projected municipal and industrial water demands for 2070 are expected to be met by extension of methods employed to satisfy the 2020 demands. The portion of the study area's 2020 high quality municipal and industrial demands satisfied from streams of improved quality is 25 percent. Expectations are that this ratio will increase to approximately 50 percent by 2070. Application of this ratio to 2070 study area water needs results in a total of 4,200 mgd that is expected to be obtained from affected streams (see Figure V-1). The net increase in water requirements supplied by affected streams from 2020 to 2070 then is 2,989 mgd.

The value of benefits to additional municipal and industrial water use after 2020 is based on the total benefit to water use ratio established for the two basins for the year 2020. An analysis of the value estimates is shown below.

Total projected 2020 municipal and industrial water needs to be supplied from improved quality streams and for which benefits are determined (See Table V-1)	1,211 mgd
Average Annual Value of Benefits in the Year 2020 (See Table V-1)	\$ 20,886,000
Average Annual Value of 2020 Municipal and Industrial Benefits per million gallons of 2020 Water use	
$\frac{\$20{,}886{,}000}{1211 \times 365}$	\$ 47.30/mg
Net increase in Municipal and Industrial Water Requirements Supplied from Improved Quality Streams from 2020 to 2070	2,989 mgd
Average Annual 2070 Municipal and Industrial Water Supply Benefit	\$ 51,621,000
Capitalized worth in the year 2020 of benefits (Figure V-2, Detail e) to increased municipal and industrial water use	
$\frac{\$51{,}621{,}000}{50} \times 503.21001$ [1]	\$519,524,000
Worth discounted to the year 1970 (Figure V-2, Detail e)	
\$519,524,000 x 0.22811 [2]	\$118,509,000
Average Annual Value of Benefit for 100 years @ 3 percent (Figure V-2, Detail f)	
\$118,509,000 x 0.031646 [3]	\$ 3,750,000

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[1] Factor to determine the capitalized value or present worth of an increasing annuity from 2020 to 2070 using 3 percent interest rate.

[2] Factor to determine the worth in 1970 by discounting the value in 2020 using 3 percent interest rate.

[3] Factor to determine the annuity for 100 years, associated with the 1970 value of benefits, using 3 percent interest rate.

42 percent 2020 to 2070 water use in affected reaches of Arkansas River 0.42 x $3,750,000	$1,575,000
58 percent 2020 to 2070 water use in affected reaches of Red River 0.58 x $3,750,000	2,175,000

Different methods are necessary for determining value of benefits to agricultural water needs than those used for municipal and industrial water needs. Value of benefits to agricultural uses is assumed to be equal to the expected net increase in farm income made possible by improvement in the quality of irrigation waters. In determining the value of agricultural benefits that will accrue with an improvement in water quality, it was assumed that in the absence of water quality improvement there will be little if any use of irrigation waters from the two river systems when the dissolved solids concentration exceeds that amount indicated by an electrical conductivity of 1,000 micromhos. It is recognized that some irrigation does occur in reaches of the stream now considered too highly mineralized for agricultural uses. Also, there are plans for project-type irrigation in some areas where electrical conductivity of the water exceeds 1,000 micromhos which may be constructed even though there is no future water quality improvement in the Arkansas and Red Rivers. However, the use of poor quality water for irrigation results in increased production costs (leaching, drainage, and management costs) as well as a decrease in gross farm income caused by reduction of crop yields and the inability to grow high value-low salt tolerant crops. Because of this, it is felt that in most cases there will be no incentive for use of irrigation waters from the Arkansas and Red Rivers without water quality improvement. It is expected that the value of benefits derived in the following analysis represents the minimum value which will accrue to irrigation with improvement of water quality in the two river basins.

Examination of the projected agricultural water needs, discussed in Chapter III, and the projected stream quality and quantity in the Arkansas and Red River basins indicates that significant contributions to agricultural production will be achieved in two general areas of the two river systems. These include: The Red River between Denison Dam and Shreveport, Louisiana and the Arkansas River between Wichita, Kansas and Van Buren, Arkansas. Total acreage benefited by water quality improvement appears by type-of-farming areas in Table V-2.

Table V-2

Projected Acreages Benefited Along Stream Reaches Affected by Water Quality Improvement

(1,000 acres)

Type-of-Farming Area	Irrigated From Surface Sources		Increase	Along Benefit Stream Reaches
	1959	Projected 2020		
1	511	510	-1	
2	50	60	10	
3	3	18	15	
4	52	70	18	
5	3	31	28	10
6	3	48	45	15
7	8	43	35	15
8	3	108	105	
9	11	232	221	
10	7	178	171	
11	94	864	770	
Total	745	2,162	1,417	40

For each type-of-farming area where benefits would accrue from the water quality improvement, an analysis was made to determine the net return to land risk and management for irrigated and nonirrigated cropping patterns. To provide benchmark data, a preliminary analysis of annual value of benefits per acre is made using present prices, costs, yields, and cropping patterns. A summary of these calculations appears in Table V-3. For actual value of benefit estimations, however, projected prices, costs, and yields were used.

Projected prices, based on an all product index of 235 (1910-1914 = 100), are those published by the U.S. Department of Agriculture in 1957.[1] These projections represent the level of prices expected to prevail over a long period of time, under assumptions of relatively high employment, a trend toward peace, continued population and economic growth, a reduction of farm surpluses and a stable general price level. Rapidly changing technology in agriculture and the associated change of price-cost relationship, however, could result in prices different from those projected.

Projected yields and fertilizer needs, developed on the basis of work done by Texas A & M[2] are fitted to each type-of-farming area on the basis of rainfall, climate, and soil types. Only those dryland and irrigated yield projections for soil types which would normally be irrigated are extracted from the Texas data for application to the study area.

Table V-3

Net Returns From Irrigated and Dryland Farming, Using Present Prices, Costs, and Yields

Crop	Per-cent	Yield	Income Per Acre	Costs Per Acre	Net Returns	Net Return Difference
Type-of-Farming Area 5						
Dryland						
Wheat	40	20 Bu.	41.90	28.10	13.80	14.20
Soybeans	35	20 Bu.				
Corn	15	35 Bu.				
G. Sorghum	10	30 Bu.				
Alfalfa	5	2.0 T.				
Irrigated						
Alfalfa	50	3.0 T.	69.90	41.90	28.00	
Pasture	25	5 AUM				
G.Sorghum	10	40 Bu.				
Corn	10	45 Bu.				
Wheat	5	25 Bu.				
Type-of-Farming Area 6						
Dryland						
Corn	25	30 Bu.	55.20	34.10	21.10	14.40
G.Sorghum	25	30 Bu.				
Cotton L.	20	250 Lbs.				
Cotton S.		425 Lbs.				
Wheat	20	19 Bu.				
Peanuts	10	1,200 Lbs.				
Irrigated						
Alfalfa	55	3.5 T.	93.50	58.00	35.50	
Pasture	10	5 AUM				
G.Sorghum	10	60 Bu.				
Cotton L.	10	400 Lbs.				
Cotton S.		720 Lbs.				
Wheat	10	33 Bu.				
Peanuts	5	1,500 Lbs.				

Table V-3 (Continued)

Crop	Per-cent	Yield	Income Per Acre	Costs Per Acre	Net Returns	Net Return Difference
Type-of-Farming Area 7						
Dryland						
Cotton L.	30	300 Lbs.	66.80	37.10	29.70	14.90
Cotton S.		540 Lbs.				
Wheat	30	30 Bu.				
G.Sorghum	25	40 Bu.				
Corn	10	30 Bu.				
Alfalfa	5	2 T.				
Irrigated						
Alfalfa	30	3.5 T.	120.55	75.95	44.60	
Cotton L.	20	450 Lbs.				
Cotton S.		810 Lbs.				
Peanuts	15	1,500 Lbs.				
Vegetables	10	100 CWT				
G.Sorghum	10	50 Bu.				
Wheat	10	30 Bu.				
Corn	5	50 Bu.				

Projected cropping patterns for each type-of-farming area are based on data developed for the U.S. Study Commission-Texas. [3] These data estimate the crop increases (both irrigated and dryland) needed to supply future demands for food and fiber. Crop increases are applied to present irrigated and dryland cropping patterns to produce future cropping patterns for each type-of-farming area.

Projected production costs are developed on the basis of present costs since no projected cost data are available. The procedure involves estimating costs of production for future yields from present costs associated with various yield levels, and adjusting these costs by a prices paid by farmers index of 265. Present production cost data, developed from various sources, [4-9] include cost of land development, pumping and delivery, labor, seed, fertilizer, insecticide, repair, depreciation, custom work, interest, machinery, taxes, water, and miscellaneous.

A summary of calculations used to arrive at annual benefits per acre appears in Table V-4.

Table V-4

Net Returns From Irrigated and Dryland Farming, Using Projected Prices, Costs, and Yields

Crop	Percent	Yield	Income Per Acre	Costs Per Acre	Net Returns	Net Return Difference
		Type-of-Farming Area 5				
Dryland						
Soybeans	35	28 Bu.	55.20	41.00	14.20	17.80
Wheat	30	20 Bu.				
Corn	20	55 Bu.				
G.Sorghum	10	51 Bu.				
Alfalfa	5	2.3 T.				
Irrigated						
Alfalfa	55	3.5 T.	104.60	72.60	32.00	
G.Sorghum	25	124 Bu.				
Corn	15	110 Bu.				
Wheat	5	35 Bu.				
		Type-of-Farming Area 6				
Dryland						
Corn	30	55 Bu.	81.10	62.70	18.40	21.25
G.Sorghum	30	51 Bu.				
Cotton L.	30	417 Lbs.				
Cotton S.		709 Lbs.				
Wheat	10	20 Bu.				
Irrigated						
Alfalfa	40	4.2 T.	165.15	125.50	39.65	
G.Sorghum	30	134 Bu.				
Cotton L.	30	830 Lbs.				
Cotton S.		1,494 Lbs.				
Wheat	5	35 Bu.				
Corn	5	110 Bu.				

Table V-4 (Continued)

Crop	Per-cent	Yield	Income Per Acre	Costs Per Acre	Net Returns	Net Return Difference
Type-of-Farming Area 7						
Dryland						
Cotton L.	30	417 Lbs.	76.85	59.55	17.30	22.20
Cotton S.		709 Lbs.				
G.Sorghum	25	51 Bu.				
Corn	20	55 Bu.				
Wheat	20	20 Bu.				
Alfalfa	5	2.3 T.				
Irrigated						
Alfalfa	30	4.2 T.	161.80	122.30	39.50	
Cotton L.	25	830 Lbs.				
Cotton S.		1,494 Lbs.				
G.Sorghum	20	124 Bu.				
Vegetables	15	250 CWT				
Corn	10	110 Bu.				

Utilizing data developed in Tables V-2 and V-4, the annual value of benefits to agriculture for a 100-year period (1970 to 2070) is estimated as shown below.

Arkansas River Basin

Area 5 - 10,000 acres x $17.80/acre/yr. . . . $178,000
Area 6 - 15,000 acres x $21.25/acre/yr. . . . 319,000
Subtotal . . 497,000

Red River Basin

Area 7 - 15,000 acres x $22.20/acre/yr. . . . 333,000
Total Annual . $830,000

Capitalized value in 1970 of 1970-2020 agricultural benefits (Figure V-2, Detail g)

Arkansas River Basin

$\frac{\$497{,}000}{50} \times 503.21001$ 1/ $5,000,000

Average annual benefit for 100 years at 3 percent

$5,000,000 x 0.031646 2/. $158,000

Capitalized value in 1970 of 1970-2020 agricultural benefits (Figure V-2, Detail g)

Red River Basin

$\frac{\$333{,}000}{50} \times 503.21001$ 1/ $3,351,000

Average annual benefit for 100 years at 3 percent

$3,351,000 x 0.031646 2/. $106,000

Total value of 1970 to 2020 agricultural benefits over 100 years at 3 percent

$158,000 + $106,000 . . . . $264,000

Capitalized worth discounted to 1970 of 2020 to 2070 agricultural benefits (Figure V-2, Detail h)

Arkansas River Basin	
\$497,000 x25.72076 [3] x 0.228107 [4].	\$2,920,000
Red River Basin	
\$333,000 x 25.72076 [3] x 0.228107 [4].	\$1,954,000
	\$4,874,000

Average annual agricultural benefits (1970-2070) (Figure 2, detail i)

Arkansas River Basin	
(\$5,000,000 + \$2,920,000) 0.031646 [2].	\$ 251,000
Red River Basin	
(\$3,351,000 + \$1,954,000) 0.031646 [2].	\$ 168,000
	\$ 419,000

1/ Factor to determine the capitalized value or present worth of an increasing annuity from the year 1970 to 2020 using 3 percent interest rate.

2/ Factor to determine the capitalized or 2020 worth of an annuity of one (1) per year from the year 2020 to the year 2070 at 3 percent interest rate.

3/ Factor to determine the worth in 1970 by discounting at 3 percent interest rate.

4/ Factor to determine the annuity for 100 years, associated with the 1970 value of total benefits, using 3 percent interest rate.

Table V-5

Summary of the Value of 1970 to 2070 Benefits -- Improvement in Water Quality Arkansas-Red River Basins Study Area

	Average Annual Value* (1970 Worth)		
	Municipal & Industrial	Irrigation	Total
Arkansas River Basin & Adjoining Areas	3,999,000	251,000	4,250,000
Red River Basin & Adjoining Areas	8,658,000	168,000	8,826,000
TOTAL	12,657,000	419,000	13,076,000

* Over 100 years at 3 percent.

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